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by B.H. Moody and Imre S. Otvos

NEWFOUNDLAND FOREST RESEARCH CENTRE  
ST. JOHN'S, NEWFOUNDLAND  
INFORMATION REPORT N-X-171

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## ABSTRACT

This report presents data on the spruce budworm outbreak in 1978 in Newfoundland and Labrador and forecast for 1979. It describes the various sampling methods used to monitor spruce budworm population levels, the effects of natural control agents, the effects of budworm damage on stands, and the methods used to forecast population levels and damage.

In 1978 the extent of current defoliation in the productive forest of the Province declined from a high of about 2.7 million hectares in 1977 to about 1.3 million hectares. Based on egg-mass and hibernacula surveys, it was forecast that moderate to severe defoliation would occur on about 930 000 hectares on the Island. Spruce budworm population levels in Labrador would be low.

## RÉSUMÉ

Ce rapport présente les données sur l'invasion de la tordeuse des bourgeons de l'épinette en 1978 à Terre-Neuve et au Labrador ainsi que les prévisions pour 1979. On y trouve décrites les diverses méthodes de prélèvement utilisées pour contrôler les niveaux de population de la tordeuse des bourgeons de l'épinette, les résultats effectués par les agents naturels de contrôle et les méthodes utilisées pour prévoir les niveaux de population et les dégâts.

En 1978, l'étendue des forêts productives de la province affectées par la défoliation est passée de 2.7 millions d'hectares en 1977 à 1.3 million d'hectares. Les études faites pendant l'hiver ainsi que l'observation des oeufs permet de prévoir que la défoliation - de modérée à très grave - se produirait sur environ 930 000 hectares sur l'île et que la population de la tordeuse des bourgeons de l'épinette au Labrador serait peu élevée.

#### ACKNOWLEDGEMENT

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# THE STATUS OF THE SPRUCE BUDWORM IN NEWFOUNDLAND IN 1978

B.H. Moody and Imre S. Otvos

## I. INTRODUCTION

The eastern spruce budworm, Choristoneura fumiferana (Clem.), native to North America, has caused extensive damage in mainland Canada but it was considered to be only as a potentially important pest in Newfoundland until 1972, the start of the present outbreak. Scattered outbreaks of the budworm have been recorded in Newfoundland since the 1940's. However, these outbreaks were small, seldom lasted more than three years and usually collapsed without causing significant tree mortality (Otvos and Moody 1978). Consequently, the spruce budworm was not well known in Newfoundland, and only recent studies revealed the biology, habits and some of its damage (Crummey 1976, Crummey and Otvos in press, Otvos 1977, Otvos and Moody 1978, Schooley 1978).

The present outbreak of the spruce budworm started in 1971 and increased in size and intensity until 1977 when it covered about 2.7 million hectares or about 90% of the productive forests on the Island.

The history of previous spruce budworm outbreaks and the progress, status and potential of the present outbreak was discussed in detail (Otvos and Moody 1978). This report updates the status of the budworm in Newfoundland and describes the various sampling methods used in evaluating and forecasting population levels, defoliation and subsequent condition of damaged trees and stands.

## II. THE SPRUCE BUDWORM - 1978

### a. Forecast of Infestation for 1978

Egg-mass counts in September are reasonably reliable forecasters of spruce budworm abundance and defoliation in the following year. The 1977 egg-mass survey included 919 locations on the Island and 31 in Labrador. This survey indicated that the overall size of the outbreak in 1978 would decrease in the Province and budworm population levels would be lower than in 1977. The areas of moderate to severe defoliation were forecasted to be 1 012 000 ha (2,500,000 acres) in 1978 (Figure 1) (Otvos and Moody 1978).

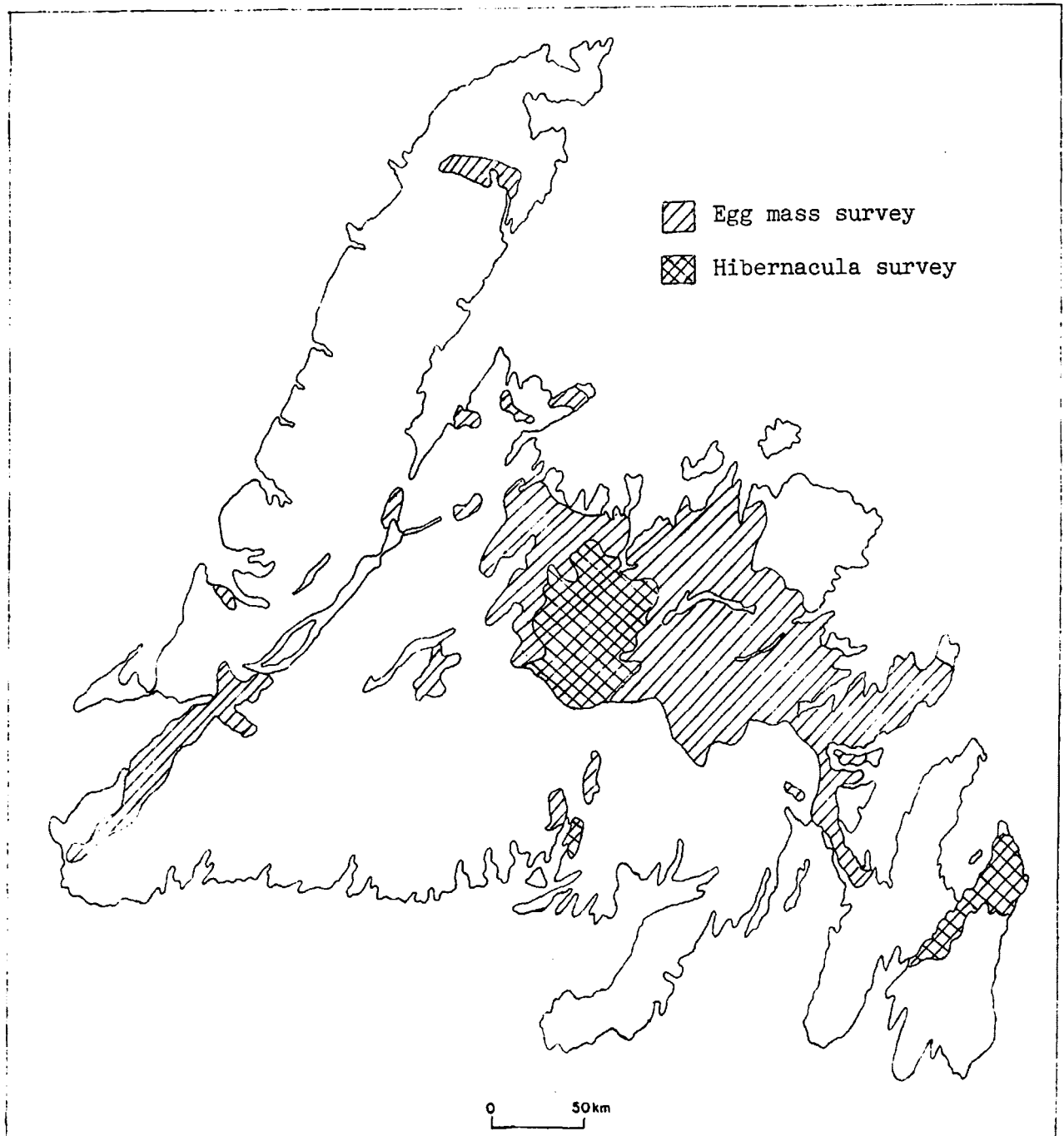


Figure 1. Areas of moderate and severe defoliation predicted for 1978 based on the egg-mass survey and the hibernacula survey.

Overwintering larvae were sampled across the Province in March 1978, to supplement the egg-mass survey and to obtain a more precise delineation of forecasted areas with moderate to high budworm densities. The larval survey included 285 locations and indicated that the budworm infestation was essentially as forecasted except for an increase in the areas of moderate to severe defoliation, to a total of 1 355 000 ha (3,347,000 acres) of fir-spruce stands on the Island. Based on the results of general observations and on a limited egg-mass survey of 31 sample points, the 1978 outbreak in Labrador was forecast to remain the same as in 1977 (Otvos and Moody 1978).

b. Host Condition

An aerial damage assessment survey in 1977 classified the merchantable coniferous forest of Newfoundland and Labrador in four categories: A - dead standing, B - moribund and not likely to recover, C - severely damaged but expected to recover and D - very lightly damaged (Figure 2). The methods of the survey are described in a subsequent report Moody (1979). The total area of stands classified as dead was about 64 000 ha (158,200 acres), containing an estimated 5 138 000 m<sup>3</sup> (2,100,000 cords) of wood. The area of moribund stands, i.e. stands with more than 75% total defoliation, was estimated at 110 500 ha (273,000 acres) with approximately 8 507 000 m<sup>3</sup> (3,500,000 cords) of wood. Mature stands severely damaged (two or more years of severe defoliation) but likely to recover totalled 774 000 ha (2,000,000 acres).

In Labrador the area of moderately to severely damaged stands totalled about 32 000 ha (79,000 acres). The volume of dead trees scattered within these stands was approximately 236 000 m<sup>3</sup> (98,100 cords). An additional 532 000 m<sup>3</sup> (220,700 cords) were classed as moribund (Otvos and Moody 1978).

c. Larval Collection and Development

The general province-wide survey conducted by the Forest Insect and Disease Survey (FIDS) began in late May and continued to mid-July. Guidelines as to methods, hosts and timing of collections were similar to those of previous years, except for the introduction of the 45 cm branch tip method for sampling budworm larvae. Emphasis was placed on the "tree-beating" methods, i.e. the 2.1 m x 3 m (7' x 9') beating sheet (Harris et al. 1972) and the 1 m x 1 m (3' x 3') beating tray (Sippell 1969) and the branch tip methods.

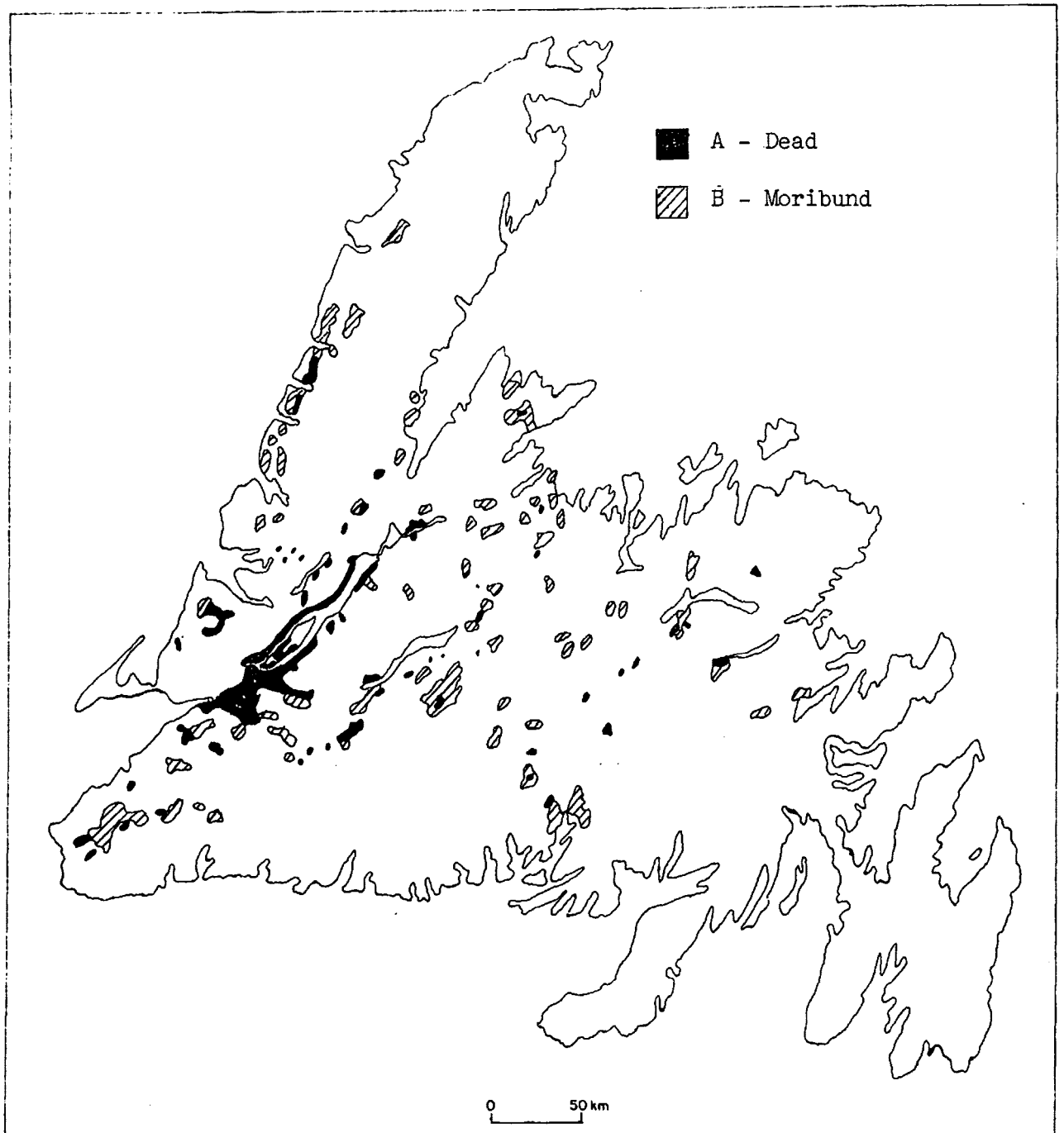


Figure 2. Areas of dead and moribund stands - 1977.

For the branch sampling method, the sample unit for larvae was one 45-cm branch tip per tree from fir or spruce. The sample unit for pupae was two 45-cm branch tips per tree from fir and four 45-cm branch tips per tree from spruce. The branches were taken from the middle of the foliated crown. Counts of budworm were made in the field and a simple classification into low or high density was made by use of sequential tables for larvae and pupae (Tables 1 and 2).

Table 1. Sequential sampling of spruce budworm larvae. Sample unit is one 45 cm tip per tree from fir and one from spruce (after Prebble 1976).

No. of sample units	Balsam fir		Spruce*	
	Population category		Population category	
	Low	High	Low	High
	Cumulative no. larvae		Cumulative no. larvae	
1	-	28 or more	-	34 or more
2	-	36	-	47
3	2 or less	43	3 or less	60
4	9	50	7	74
5	16	58	11	87

\* Developed for red spruce in New Brunswick, used for black and white spruce in Newfoundland.

Table 2. Sequential sampling of spruce budworm pupae. Sample unit is two 45 cm tips per tree from fir and four from spruce (after Prebble 1976).

No. of sample units	Balsam fir		Spruce	
	Population category		Population category	
	Low	High	Low	High
	Cumulative no. pupae		Cumulative no. pupae	
1	-	33 or more	-	9 or more
2	1 or less	50	1 or less	12
3	5	66	4	15
4	10	83	8	19
5	14	100	11	23

Larval development was a week later in 1978 than in 1977 and tree defoliation was not evident until late June and early July. Population levels were generally lower than forecast from results of the egg-mass and overwintering larval surveys, as a result of low initial larval survival, especially in western Newfoundland. This decrease resulted primarily from unfavourable weather conditions and partly from starvation due to depletion of foliage.

Approximately 96% of the FIDS 'tree beating' collections made in 1978 yield spruce budworm (all larval or pupal stages) and practically did not change from the 94% in 1977. The average number of budworm per tree sample or per 45 cm branch tip were tabulated for 1977 and 1978 (Table 3). The figures indicated a general decrease in larval numbers in the province from 1977 to 1978. However, the average larval counts in the central and eastern regions were high enough to cause moderate to severe defoliation of the current growth in 1978.

Table 3. Average number of spruce budworm larvae collected in three regions on the Island and in Labrador in 1977 and 1978.

Regions	Beating method				Branch method	
	No. of trees sampled (locations)*		No. larvae per tree sample		No. branches sampled	No. larvae per branch
	1977	1978	1977	1978	1978	1978
Western	521	441	42	13	460	3.8
Central	135	172	144	26	69	14.1
Eastern	628	259	57	25	179	8.1
Island	1284 (343)	872 (227)	60	19	708 (223)	6.0
Labrador	50 (17)	4 (2)	29	6	-	-
Total	1334	876	59	19		

\*  
No. of locations sampled in brackets.

d. Areas Treated

The extensive area infested by the budworm prompted the Provincial Government to conduct an experimental spray program in 1977. This was the first chemical control operation against the budworm in Newfoundland. Various spray regimes, using fenitrothion, Matacil, Bacillus thuringiensis and Orthene, either alone or in combination were applied treating a total of about 77 000 hectares (Carter 1977). The following year an operational spray program was conducted. Details of this spray operation have been documented (Carter 1979) and only the highlights are reviewed here.

Egg-mass and overwintering larval surveys indicated that about 1 355 000 hectares (3,347,000 acres) of forest stands would be moderately to severely infested in 1978 (Otvos and Moody 1978). Using this area of forecasted infestation the Provincial authorities selected 520 000 hectares (1.3 million acres) for treatment, but treated only 376 600 hectares (930,579 acres) (Figure 3). Treated areas received two applications of 70 gm Matacil/ha (1.0 oz/ac.). The first application was at peak third instar larvae, the second application followed five to seven days later. Two types of spray planes were used; four-engine DC-6B's and single engine Cessna AG wagon. The aerial application of insecticide reduced significantly larval numbers in the treated areas. The average overall corrected\* mortality was 61.8% (with a range of 16.0 to 76.5% between regions) and the expected defoliation was reduced by 44.8% (with a range of 35.1% to 72.8%) in stands treated by DC-6 spray planes. Corrected larval mortality averaged 76.3% (the range was 63.4% to 95.7% between regions) in stands treated by the AG wagon spray planes, and expected defoliation was reduced by 36.8% (range 8.9% to 62.7% between regions).

e. Environmental Monitoring

Environmental studies on the side effects of the aerial spraying against the spruce budworm measured the distribution and intensity of the spray deposit by determining Matacil levels in public water supplies and the persistence of Matacil residues in the forest environment, and by monitoring short term effects of the spray on populations of aquatic and terrestrial non-target organisms. The work was coordinated by the Environmental Monitoring Committee composed of representatives of federal and provincial forest agencies and the university. The results of the individual studies have been compiled and edited by Thompson (1979) and the highlights are summarized below.

Spray deposit was generally uniform in the two spray blocks monitored. Spray deposition at ground level on Kromecote cards averaged about 8% of the volume emitted from the spray aircraft. This is around

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\* Corrected for natural mortality using Abbot's (1925) formula.

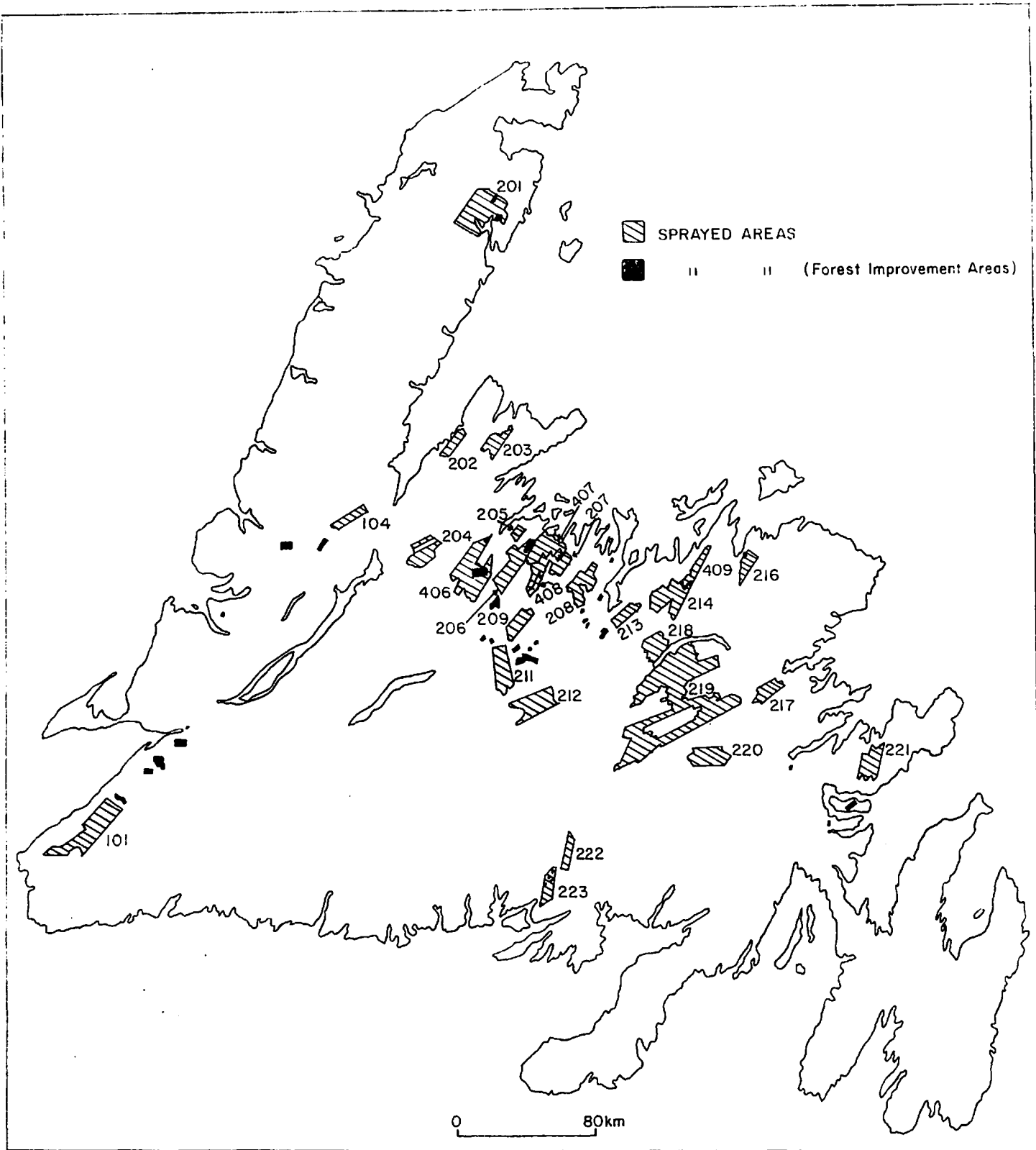


Figure 3. Areas sprayed with the insecticide Matacil in Newfoundland in 1978.

the lower end of the range obtained in operational programs conducted elsewhere. Spray drift outside the spray blocks was minimal.

Matacil residues in balsam fir foliage reached a maximum peak of 5.36 ppm shortly after the second application. The concentration of Matacil gradually declined after the second application; the half-life for the aminocarb in the forest canopy is 8 to 11 days. Aminocarb residues in the soil were extremely low.

There was no evidence of significant decrease in population levels of non-target terrestrial and soil arthropods.

Small mammal (masked shrew, Sorex cinereus) trapping showed no apparent population trends in the number of animals captured between the treated and untreated areas.

Mist-nesting of birds gave inconclusive evidence of reduced production of young in sprayed areas. However, censusing song birds showed no decline in activity or population density attributable to spraying. No unusual bird behavior was observed and no dead birds were found.

Studies of stream insects showed an immediate increase in the number of aquatic and terrestrial insects in the drift samples following spraying, but normal drift patterns resumed within 24 hours, and no spray-related impact was observed on the numbers and diversity of bottom-dwelling aquatic insects. No dead or dying fish were observed.

Water samples taken from the intake of four drinking water supplies did not contain detectable levels of Matacil.

#### f. Parasitism and Other Natural Control Factors

Spruce budworm populations were sampled during 1978 to determine the rates of parasitism caused by the various parasite groups, the prevalence of fungal disease, and the effect of the chemical insecticide Matacil on budworm parasites.

Samples were collected from each of 10 permanent points and from various additional sample points across the Island. At least three trees were sampled at each point by the standard 2.1 m x 3 m beating method at the following developmental stages: peak L<sub>3</sub> - L<sub>4</sub> instar, peak L<sub>5</sub>, and at about 70% pupation. Larvae and pupae were mass reared by location until the completion of adult emergence of budworm moth and parasites. Dead larvae and unemerged pupae were checked for the evidence of fungal disease. Presence of fungal disease was also checked in the field at each sample location.

In addition, two areas in each of eastern, central and western Newfoundland treated with the aminocarb insecticide Matacil were also sampled to examine the effect of the chemical on budworm parasites.

Three plots, at least 5 km apart, were selected in each of the spray blocks. A corresponding number of check (control) plots, from 8 to 16 km outside the boundary of the spray blocks were also sampled.

At each plot 5 dominant or codominant balsam fir trees were selected and marked and all pre- and post-spray branch samples were taken from these trees using a pole pruner. Pre-spray samples were taken one or two days before the first spray application; budworm populations were in the peak third instar at this time. Two mid-crown branches were removed from each sample tree, placed separately into plastic bags, labelled, and taken to the field station for processing where branch dimensions (length and width) and the number of budworm larvae were recorded for each branch. Larvae were reared until emergence of budworm adults and emergence of parasites.

Two post-spray samples, one for larvae and one for pupae were taken. Post-spray larval samples were taken five days after the second spray application from the same trees and in the same manner as pre-spray samples; budworm larvae were in fourth and fifth instars. Branches were taken to the laboratory where the number of live and dead larvae were recorded. Live larvae were mass reared by plot until parasite and budworm moth emergence was completed. Unemerged pupae were dissected to determine the cause of death.

Post-spray pupal samples were taken when about 70% of the budworm population was in the pupal stage. Branches were taken from the same sample trees and the same manner as before. The number of live and dead larvae and number of pupae (both emerged and unemerged) per branch were recorded. Live larvae and pupae were mass reared by plots. When it appeared in the field that 50 pupae or less would be collected an additional 50 pupae were collected at each of the plots by the standard 2.1 m x 3 m beating method. Pupae were also mass reared by plots until moth and parasite emergence was completed. If emergence of budworm adults started prior to the time of the pupal sampling the empty pupal cases were also collected and counted and were included in the total, used in calculating percent parasitism. Budworm adults usually begin to emerge about 10 days prior to parasite emergence, and their emergence holes were readily distinguishable from those made by parasites.

Previous rearing records have indicated that among the larval parasites in Newfoundland Apanteles fumiferanae Vier. and Glypta fumiferanae (Vier.) are the most important species (Otvos unpublished data). Although these two species attack first and second instar larvae of the budworm in the fall, the mature parasite larvae do not emerge from the host until it reaches the late fourth or fifth instar. A number of other parasite species can attack and develop in these early instars, however, their incidence in Newfoundland was negligible. Therefore, the results

of the rearing of the first two larval collections have been combined and percent parasitism was calculated only for Apanteles and Glypta, the two most important larval parasites. Apparent larval parasitism decreased slightly<sup>1</sup> from 10% in 1977 to 7% in 1978. Glypta spp. was about four times as numerous as Apanteles sp. (Table 4). Larval parasitism by these species was about the same, 6 to 9%, across the Island.

Pupal parasitism was the highest, about 33%, in central Newfoundland, followed by eastern (27%) and western (19%) regions of the Island. Pupal parasitism increased slightly from that of 1977 and Phaeogenes hariolus (Cress.) and Apechthis ontario (Cress.) remained the most common species. Three species of dipterous parasites (Actia interrupta (Curr.), Phryxe pecosensis (Tns.) and Eumea caesar (Ald.) also emerged from budworm pupae but were so few that their numbers have been combined and recorded as Diptera in Table 4. Phaeogenes was the most common pupal parasite, about three times as numerous as Apechthis, the second most common pupal parasite. These two pupal parasites showed the greatest increase during the current budworm outbreak in Newfoundland. Rapid increase of P. hariolus elsewhere has been associated with the decline of budworm outbreaks.

Spruce budworm parasites did not appear to be affected significantly by Matacil during the chemical control operation in 1978. Although larval parasitism by Glypta and Apanteles decreased after the spray the reduction in percent parasitism was not significant. Pupal parasitism was about the same in the spray and control areas in western and eastern Newfoundland. In central Newfoundland, however, pupal parasitism was somewhat higher in the treated than in the control areas. This apparent contradiction may be explained by the fact that budworm larval populations have been reduced drastically by the spray operation and the remaining (lower) larval population was more heavily parasitized than the higher population would have been.

Fungal infection, caused by Entomophthora spp. in 1978 was lower and not as widespread as in 1977. This was caused by the warmer and drier summer in 1978. Such weather conditions are favorable for budworm development and survival and unfavorable for fungal growth and for the spread of the disease.

#### g. Forest Conditions in 1978

##### (i) Defoliation Estimates

This was the second year in which no specific aerial defoliation survey was attempted in the Province. However, the FIDS staff mapped the outbreak according to visible defoliation from aerial and ground

<sup>1</sup> Apparent parasitism refers to the proportion of hosts (budworm) attacked by the parasites and it is determined from a sample drawn from the host population.

Table 4. Spruce budworm parasitism by geographic regions, 1978.

Location	No. host larvae reared	Larval parasitism*			No. host pupae reared	Pupal parasitism*			
		A	G	Total		Ph.h.	A.o.	Dip- tera	Total
Western									
Barry Brook	137	0.7	6.6	7.3	290	16.9	4.8	1.7	23.4
Hughes Brook	67	1.5	6.0	7.5	142	17.6	5.6	2.8	26.0
Sandy Lake	33	3.0	6.1	9.1	248	15.7	4.4	7.7	27.8
Trout Brook	21	0	4.8	4.8	-	-	-	-	-
Mummichug	176	1.1	5.1	6.2	120	15.0	5.8	3.3	24.1
Bald Mtn.	38	2.6	7.9	10.5	122	12.3	5.7	2.5	20.5
Barachois P.									
Park	168	0.6	1.8	2.4	98	13.3	5.1	3.1	32.7
Reidville	197	1.0	2.5	3.5	102	11.8	2.9	2.0	16.7
South Brook V.	125	0.8	1.6	2.4	60	15.0	5.0	5.0	25.0
Pasadena	340	0.8	9.6	10.4	27	14.8	7.4	3.7	25.9
Crabbes R.	70	1.4	8.6	10.0	-	-	-	-	-
Doyles	20	0	5.0	5.0	-	-	-	-	-
Nicholsville	-	-	-	-	42	16.7	4.8	0	21.5
Searston	-	-	-	-	36	19.4	2.8	0	22.2
Total for region	1412	0.9	4.8	5.7	1287	15.4	5.0	3.4	18.8
Central									
Badger	258	1.9	8.5	9.4	181	17.7	7.2	4.4	29.3
Grand Falls	283	0.7	2.5	3.2	170	25.3	8.2	0	32.5
Baie Verte	43	2.3	2.3	4.3	109	18.3	6.4	2.8	27.5
Lake Ambrose	19	0	5.3	5.3	146	26.0	8.9	1.4	36.3
Glenwood	66	4.5	10.6	15.1	42	26.2	14.3	2.4	42.9
Baie Verte Jct.	69	4.3	8.7	13.0	22	27.3	4.5	0	31.8
LaScie									
West Point	91	1.1	8.8	9.9	-	-	-	-	-
Millertown	161	1.9	6.8	8.7	-	-	-	-	-
Buchans Rd.	118	3.4	7.6	12.0	-	-	-	-	-
Gander	19	0	5.3	5.3	-	-	-	-	-
Bay D'Espoir	127	5.5	10.2	15.7	-	-	-	-	-
Total for region	1254	2.3	6.9	9.2	670	22.4	8.1	2.1	32.6

Cont'd ...

Table 4 - Concluded

Location	No. host larvae reared	Larval parasitism*			No. host pupae reared	Pupal parasitism*			
		A	G	Total		Dip-			
						Ph.h.	A.o.	tera	Total
		%	%	%		%	%	%	%
Eastern									
Random Island	41	2.4	4.9	6.3	160	21.9	3.1	0	25.0
Bunyan's Cove	92	2.2	6.5	8.7	16	31.3	6.3	0	37.6
Paddy's Pond	173	1.7	5.9	7.6	65	20.0	3.1	3.1	26.2
Bellevue	120	1.7	5.0	6.7	-	-	-	-	-
Port Blandford	-	-	-	-	108	19.4	7.4	0.9	27.7
Clareville	-	-	-	-	26	23.1	7.7	3.8	34.6
Total for region	426	1.2	5.6	6.8	375	21.3	4.8	1.6	27.7
Grand Total	3092	1.6	5.8	7.4	2332	18.4	5.8	2.7	26.9

\* A = Apanteles fumiferanae, G = Glypta fumiferanae, Ph.h. = Phaeogenes hariolus  
A.o. = Apechthis ontario

observations made during damage assessment and other types of surveys and from estimates of defoliation at egg-mass sample points in September 1978. These observations were delineated on topographic maps and stratified into the following current defoliation classes; light - 0-25%, moderate - 26-75% and severe 76 - 100%.

The areas of moderate to severe defoliation for 1977 and 1978 are shown in Figures 4 and 5. In 1978, the spruce budworm outbreak, as indicated by the extent of current defoliation (light, moderate and severe) in the productive forests of the Island, declined from a high of 2 730 500 hectares (6,747,300 acres) in 1977 to 1 341 800 hectares (3,315,700 acres) (Table 5).

In western Newfoundland moderate to severe defoliation occurred from Doyles to Flat Bay Brook, near Glide Lake between Deer Lake and Grand Lake, from Roddickton to Main Brook on the Northern Peninsula, and from Freshwater Pond to Burlington on the Baie Verte Peninsula. In central and eastern regions, moderate to severe defoliation was recorded

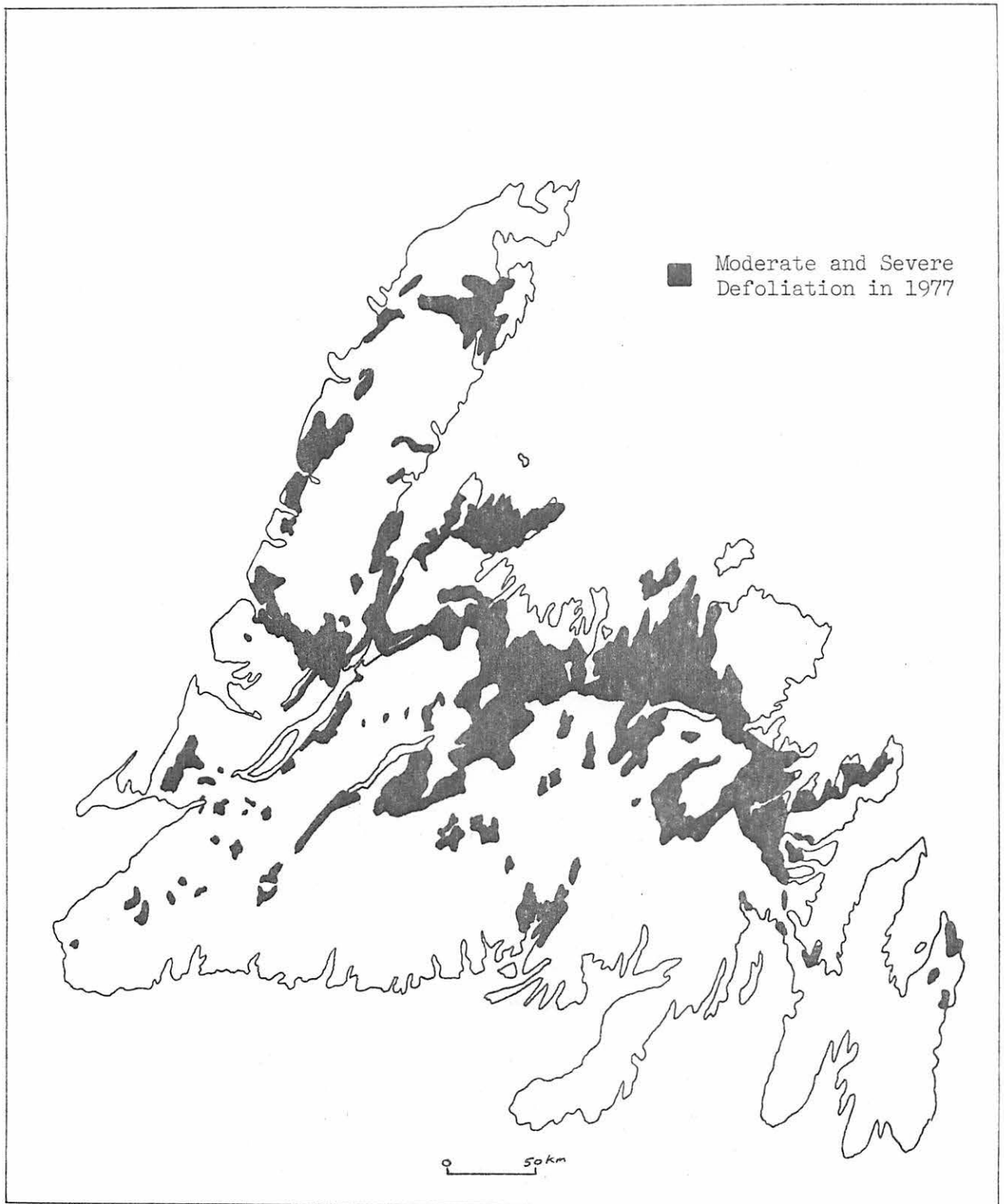


Figure 4. Moderate to severe defoliation caused by the spruce budworm in Newfoundland in 1977.

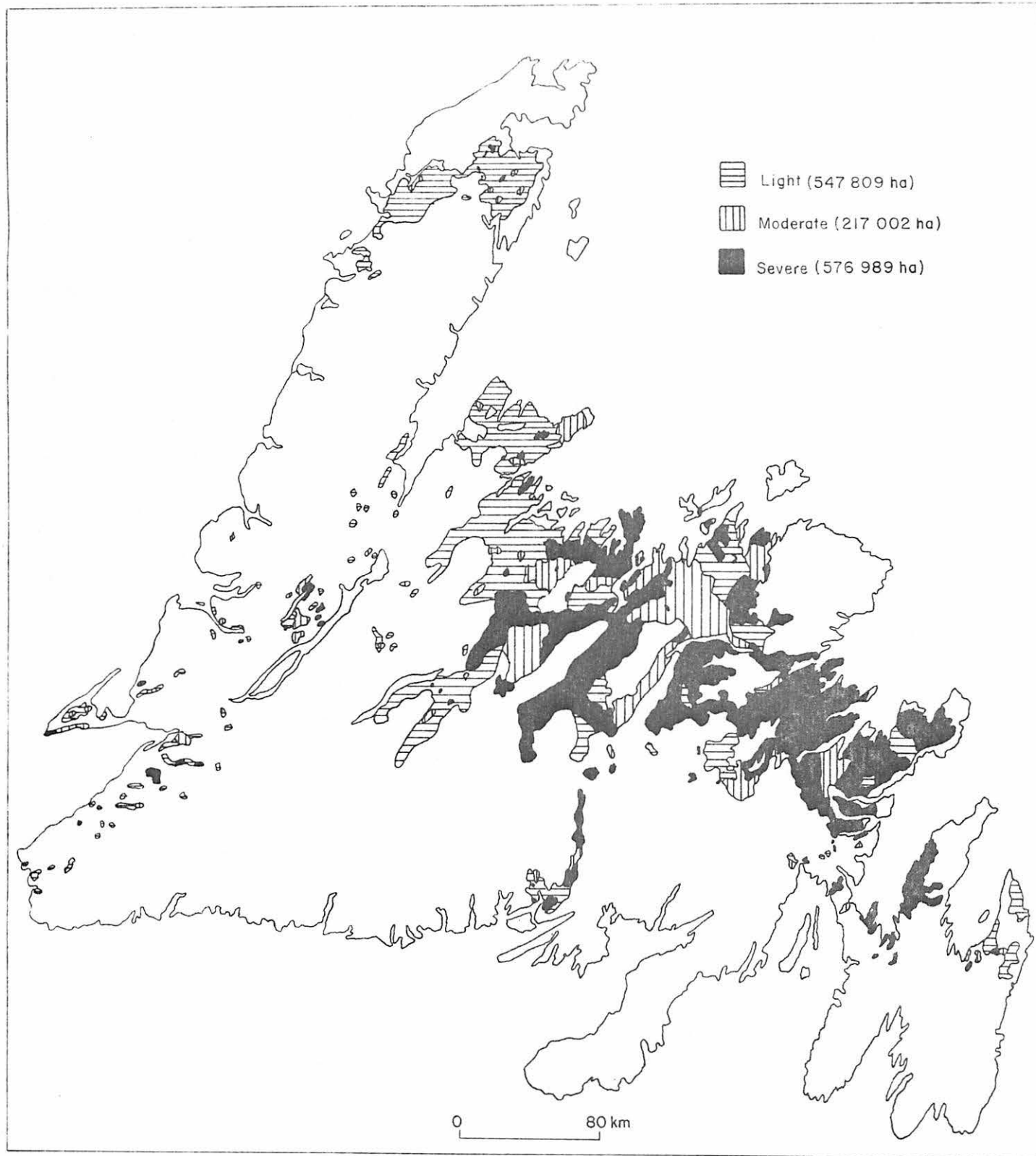


Figure 5. A. Defoliation caused by the spruce budworm in Newfoundland in 1978.

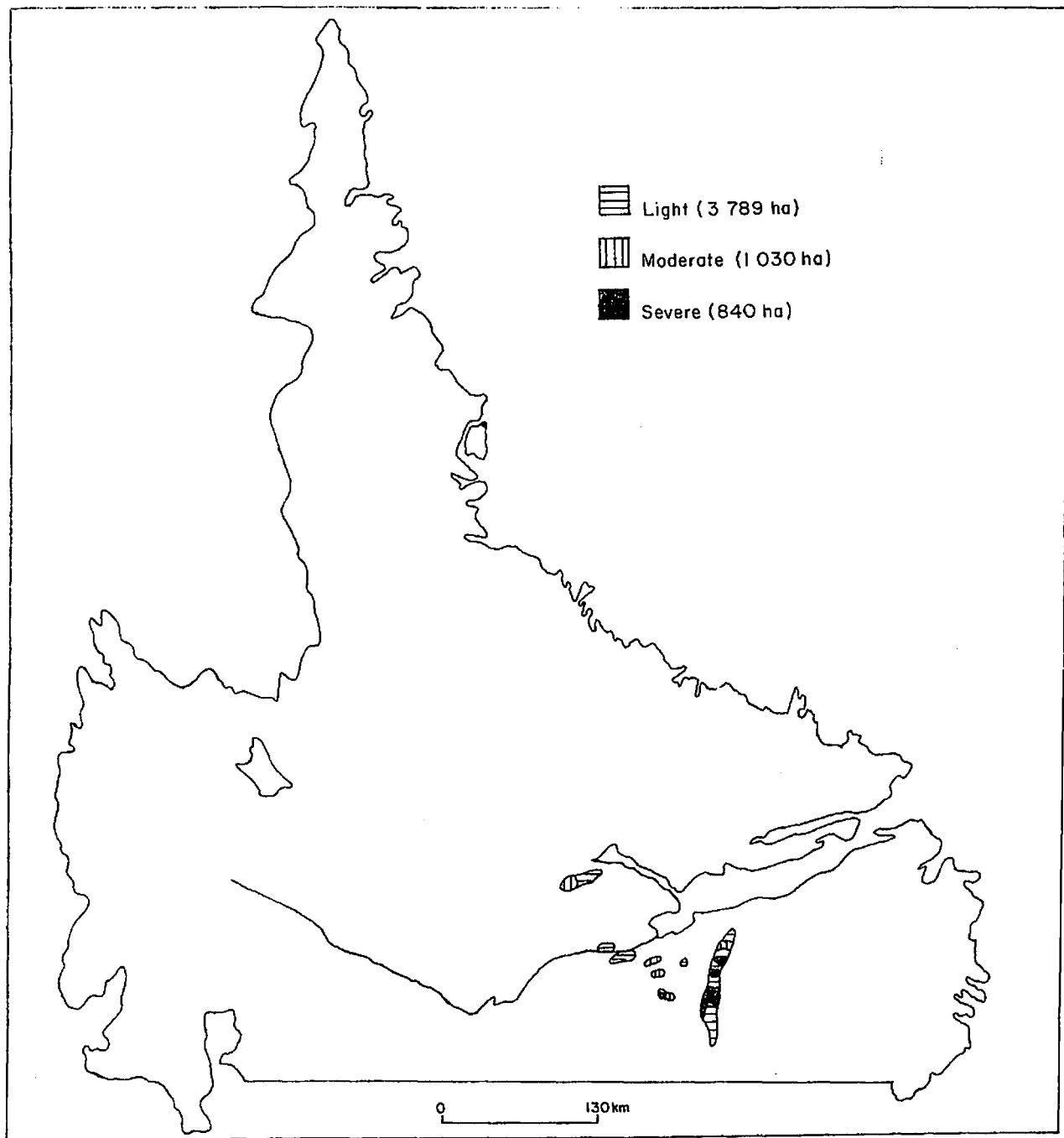


Figure 5. B. Defoliation caused by the spruce budworm in Labrador in 1978.

Table 5. 1978 Spruce budworm defoliation in productive forests\* of Newfoundland and Labrador.

Management unit no.	Defoliation			
	Light	Moderate	Severe	Total
	Hectares	Hectares	Hectares	Hectares
1		495	29 114	29 609
1A	14 551	1 072	1 030	16 653
2	15 205	19 025	113 000	147 230
3	83	662		745
4	16 671	11 649	39 658	67 978
5	19 841	25 660	115 255	160 756
6	18 303	18 753	72 823	109 879
7	16 779	2 630	7 194	26 603
8	36 536	55 560	56 037	148 133
9	172 317	14 888	14 100	201 305
10	28 600	36 200	33 078	97 878
11	15 895	18 679	87 649	122 223
12	54 122	969	3 565	58 656
14	10 888	3 163	1 953	16 004
15	2 318	5 315	823	8 456
16	7 990	961	532	9 483
17	34 344	329		34 673
18	83 366	992	1 178	85 536
Total Island	547 809	217 002	576 989	1 341 800
Labrador	3 789	1 030	840	5 659
Total	551 598	218 032	577 829	1 347 459

\*Productive Forests: Stocked land that is capable of producing a merchantable stand within a reasonable length of time.

from Halls Bay to Red Indian Lake, from Badger east to Random Island including the Bonavista Peninsula, in the Bay D'Espoir area, along the Trans Canada Highway near the Fairhaven Road, on the Bellevue Peninsula and along Manuels River near St. John's. Many of the spruce stands in central and eastern Newfoundland were also infested by the spruce coneworm (Diorcytria reniculelloides Mut. & Mun.), at times comprising about half of the larvae in the samples, which also contributed to the severe defoliation.

In Labrador the area of defoliation decreased from 52 700 hectares (131,000 acres) in 1977 to about 5 700 hectares (14,100 acres) in 1978. Only light to moderate defoliation occurred in the Kenamu River Valley, Otter Creek and Mud Lake areas.

(ii) Damage Assessment Survey

An aerial damage assessment survey augmented with ground checks was conducted in August 1978 to determine the area and volume of dead and damaged stands. This survey differed from that of 1977 in that it classified the merchantable stands based on percent dead or moribund trees according to the following categories:

- A - Dead: 50% or more of total volume of the stand dead.
- B - Moribund, unlikely to recover: 20%-49% of total volume dead or more than 50% of total volume dying (dying = 75% or more total defoliation).
- C - Very severe damage, likely to recover: 5%-19% of total volume dead or less than 50% of total volume dying.
- D - Severe damage, likely to recover: severe damage but less than 5% dead or dying trees.

The results showed that not only was mortality increasing in areas already affected but the total areas where mortality was occurring had also increased. The total area of merchantable stands with dead and dying trees increased from about 174 500 hectares (431,000 acres) in 1977 to 300 400 hectares (742,000 acres) in 1978 (Table 6). These stands contained a total volume of about 6 547 000 m<sup>3</sup> (2,717,000 cords) of dead trees and 4 841 000 m<sup>3</sup> (2,009,000 cords) of dying trees in 1978. It is important to note that the total volume of stands classified as A, B and C (i.e. stands containing dying and dead trees) increased from an estimated 15 354 000 m<sup>3</sup> (6,371,000 cords) in 1977 to 22 399 000 m<sup>3</sup> (9,294,000 cords) in 1978. The area of stands classified as D was about 639 000 hectares (1,580,000 acres) but no volumes were estimated.

Table 6. Spruce budworm damage assessment survey in merchantable stands in 1978. Volume based on 2.41 m<sup>3</sup>/cord.

Man- age- ment unit no.	Ownership	Area and volume affected											
		A (Dead)*				B (Moribund)*				C (Very severe damage)*			
		Total area (ha)	Total vol. (m <sup>3</sup> )	Dead vol. (m <sup>3</sup> )	Dying vol. (m <sup>3</sup> )	Total area (ha)	Total vol. (m <sup>3</sup> )	Dead vol. (m <sup>3</sup> )	Dying vol. (m <sup>3</sup> )	Total area (ha)	Total vol. (m <sup>3</sup> )	Dead vol. (m <sup>3</sup> )	Dying vol. (m <sup>3</sup> )
1	Crown	-	-	-	-	1 947	67 367	1 518	52 374	710	40 389	-	13 429
2	Crown	-	-	-	-	74	7 531	-	4 519	926	40 061	-	5 408
4	Price	552	36 516	29 214	-	4 387	262 892	46 205	128 945	2 061	189 359	-	46 730
5	Crown	-	-	-	-	-	-	-	-	832	83 675	-	30 593
	Bowaters	-	-	-	-	226	22 902	-	13 739	338	34 251	1 012	6 326
	Price	422	42 691	25 613	-	156	14 807	-	8 883	2 072	143 084	13 879	21 463
6	Crown	143	8 165	5 717	-	-	-	-	-	-	-	-	-
	Bowaters	-	-	-	-	8 009	791 212	202 734	3 817	2 012	191 462	24 524	31 790
	Price	-	-	-	-	-	-	-	-	296	29 896	-	11 958
7	Crown	1 368	63 525	58 690	-	6 912	353 436	75 189	180 092	9 331	572 673	53 200	147 800
8	Crown	-	-	-	-	442	48 200	-	28 920	2 027	126 802	3 977	10 151
	Bowaters	-	-	-	-	-	-	-	-	816	23 273	-	6 982
9	Crown	3 485	242 916	175 499	36 360	2 000	213 280	47 190	97 552	2 753	182 063	583	48 287
	Bowaters	3 629	296 256	216 924	48 116	10 109	905 244	256 930	312 970	6 618	572 879	2 463	153 146
10	Crown	-	-	-	-	-	-	-	-	1 027	31 316	5 825	8 830
	Price	3 950	133 861	98 248	9 315	3 296	186 539	67 121	56 628	6 988	263 611	24 078	61 761
11	Price	-	-	-	-	2 240	86 955	-	52 174	159	12 725	-	2 545
12	Crown	68	5 900	5 131	-	-	-	-	-	-	-	-	-
	Price	6 770	461 927	363 308	27 358	1 658	122 517	11 327	53 825	1 149	76 840	831	12 971
13	Price	150	15 694	10 985	-	1 571	125 161	46 323	4 593	1 777	135 828	12 026	6 227
14	Crown	16 571	955 495	617 606	161 058	12 297	1 069 457	342 316	229 687	14 501	1 213 888	213 215	264 681
	Bowaters	5 759	461 363	290 875	43 802	21 433	1 792 707	703 734	205 727	12 791	1 066 420	153 825	249 999
15	Crown	-	-	-	-	4 696	400 940	104 242	68 639	1 505	107 582	-	18 863
	Bowaters	10 290	796 693	537 963	98 198	13 487	1 184 067	362 772	259 145	15 187	1 207 983	123 619	119 513
16	Crown	-	-	-	-	9 965	899 123	95 788	440 926	6 329	484 364	44 180	148 066
	Bowaters	4 128	318 448	209 945	41 744	7 089	529 506	138 864	175 046	4 687	336 146	44 510	103 999

Cont'd ...

Table 6. - Concluded

Man- age- ment unit no.	Ownership	Area and volume affected											
		A (Dead)*				B (Moribund)*				C (Very severe damage)*			
		Total area (ha)	Total vol. (m <sup>3</sup> )	Dead vol. (m <sup>3</sup> )	Dying vol. (m <sup>3</sup> )	Total area (ha)	Total vol. (m <sup>3</sup> )	Dead vol. (m <sup>3</sup> )	Dying vol. (m <sup>3</sup> )	Total area (ha)	Total vol. (m <sup>3</sup> )	Dead vol. (m <sup>3</sup> )	Dying vol. (m <sup>3</sup> )
17	Crown	3 076	85 555	49 600	16 593	1 659	147 492	5 350	95 588	506	50 610	-	8 315
	Bowaters	5 832	382 036	232 659	84 430	275	18 027	6 309	2 704	3 628	282 170	14 607	57 057
	GMNP	193	12 356	11 120	-	12 736	828 763	271 518	133 167	4 130	319 785	51 967	30 744
14	Private	-	-	-	-	-	-	-	-	2 181	181 858	34 188	36 372
All	Crown	24 711	1 361 556	912 242	214 010	39 991	3 206 826	671 594	1 198 298	40 447	2 933 425	320 968	704 421
	Bowaters	29 638	2 254 796	1 488 365	316 288	60 629	5 243 666	1 671 345	973 148	46 077	3 714 586	364 560	728 842
	Price	11 844	690 689	527 368	36 673	13 307	798 872	170 975	305 048	14 501	851 342	50 815	163 656
	GMNP	193	12 356	11 120	-	12 736	828 763	271 518	133 167	4 130	319 785	51 967	30 744
	Private	-	-	-	-	-	-	-	-	2 181	181 859	34 188	36 372
Total Island**		66 386	4 319 397	2 939 096	566 972	126 664	10 078 126	2 785 432	2 609 661	107 336	8 000 998	822 499	1 664 035
Total Island (Area in acres, vol. in cords)		164 045	1 792 281	1 219 542	235 258	312 994	4 181 795	1 155 781	1 082 847	265 234	3 319 916	341 286	690 471

\*A (Dead): 50% or more of total volume of stand dead.

B (Moribund, unlikely to recover): 20% to 49% of total volume of stand dead or more than 49% of total volume dying.

C (Very severe damage, likely to recover): 5% to 19% of total volume dead or 5% to 49% of total volume dying.

GMNP, Gros Morne National Park

\*\* These figures have been converted directly from English to metric measurements, therefore columns do not total exactly.

In Labrador in 1978 the volume of dead and dying trees, scattered in the much reduced infestation and in the previously damaged areas, has not increased appreciably from 770 000 m<sup>3</sup> (320,000 cords) reported in 1977.

Aerial damage assessments were also conducted in submerchantable young stands of fir on the Island. The area of stands in the moderate to severely damaged category decreased from 692 000 hectares (1,700,000 acres) in 1977 to about 356 000 hectares (879,000 acres). However, the area of very severely damaged stands containing mortality increased from 20 000 hectares (50,000 acres) to 32 000 hectares (78,000 acres) in 1978.

Young balsam fir stands were also surveyed on the ground to assess damage by the budworm. These young stands were grouped into categories according to years of severe defoliation. Mortality occurred in stands with 4 years severe defoliation. It should be noted that some of these stands were initially under stress from damage by other insects before the budworm outbreak. A high percentage of the trees, that were predicted in 1977 to die, have now died. Mortality in stands in the Harry's River, Furries Brook and Trout Brook areas ranged from 9% to 100%. There was little or no mortality in stands with less than 3 years of severe defoliation, however, top-killing continued to occur. In stands with low insect population, good recovery was evident as replacement of dead leaders by lateral branches was common.

### III. FORECAST FOR 1979

#### a. Egg-Mass Survey

In September 1978 an egg-mass survey was conducted to provide an indication of the expected spruce budworm population and defoliation levels in 1979. This survey covered the entire Island and the infested portion of Labrador, 854 locations and 15 locations were sampled, respectively. Egg-mass samples consisted of one mid-crown branch from each of three balsam fir or three spruce trees per sample point. The mid-crown of a tree was the mid-point of the foliated portion of the tree crown. To calculate surface area of the foliage, the foliated length and foliated width at half the foliated length of the branch were measured (allowance was made for defoliation).

Samples were sent to the Newfoundland Forest Research Centre and were searched for egg-masses. When egg-masses were found, the needles on which they were attached were separated from the branch and saved for examination by trained personnel. Egg-masses were classed in one of the following categories:

1. New - unhatched (green in color)
2. New - hatched (opaque white)
3. New - parasitized (black)
4. Old - from previous year's population

The number of new unparasitized egg-masses (categories 1 and 2) expressed as egg-masses per 10 m<sup>2</sup> was calculated separately for each branch of the sample. This value was compared with figures in a sequential table (Table 7) to obtain expected defoliation levels (Webb et al. 1956). Searching of additional branches ceased when the cumulative egg-mass count fell into a sequential category which was used to express infestation levels. The infestation levels used were light, moderate, and high; the moderate level was the uncertain category in the sequential table.

Table 7. Sequential table for spruce budworm egg-mass surveys designed to predict whether insect populations are likely to cause light (less than 29%) or severe (more than 72%) current defoliation. Based on revised  $k = 2.394$ , pole pruner method (after Webb et al. 1956).

Branch no.	Cumulative number of egg-masses per 10 m <sup>2</sup>		
	Light	Uncertain (moderate)	Severe
1	-	0-337	More than 337
2	Less than 149	149-505	" " 505
3	" " 315	315-672	" " 672

The egg-mass survey on the Island indicated that the size of the outbreak would decrease in 1979 and in some locations population levels would be lower than those in 1978. The area of moderate and severe defoliation was forecast to be about 740 000 hectares (1,829,000 acres) distributed predominantly in central and eastern Newfoundland from Red Indian and Twin Lakes to Bay D'Espoir and east to Random Island including the Bonavista Peninsula and a few isolated locations on the Avalon Peninsula (Figure 6 and Table 8). In western Newfoundland only a few areas were forecast to remain in the severe defoliation category in 1979 including the Codroy Valley, Fishell's River and the Barry Brook areas.

In Labrador, the outbreak was expected to virtually collapse in 1979. Moderate defoliation was forecast to occur only in one small area.

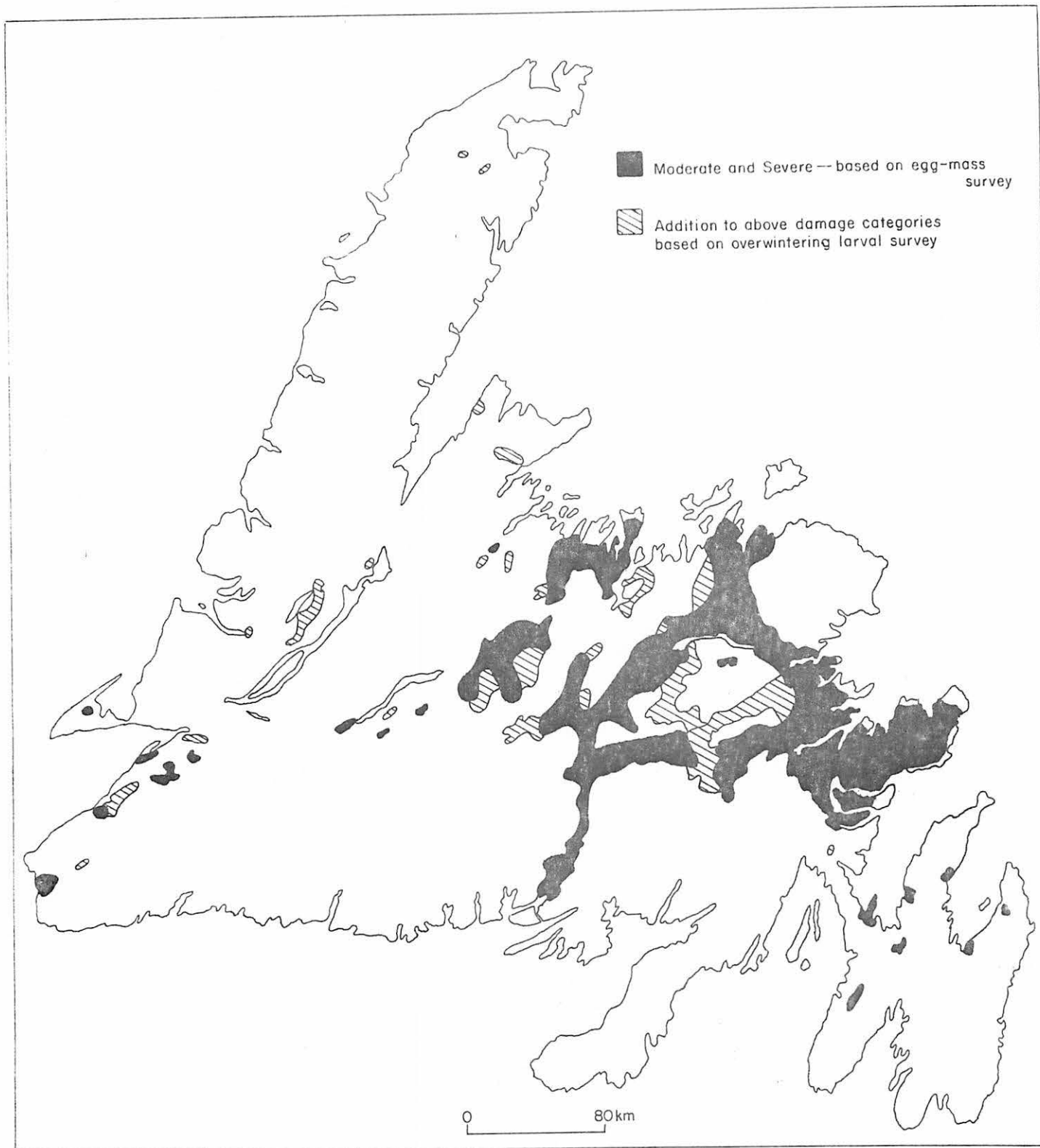


Figure 6. Areas of moderate and severe defoliation forecast for 1979 based on egg-mass and overwintering larval surveys.

Table 8. Areas of moderate and severe defoliation and areas of moderate and high hazards forecast for 1979 based on egg-mass and overwintering larval surveys.

Manage- ment unit no.	Ownership	Areas of moderate and severe defoliation (hectares)			Areas of moderate to high hazard (hectares)		
		Based on egg-mass survey	Change based on overwintering larval survey	Total area	Based on egg-mass survey	Change based on overwintering larval survey	Total area
1	Crown	16 922		16 922	5 574		5 574
1A	Crown	2 257		2 257	2 491		2 491
2	Crown	152 499	288	152 787	41 484		41 484
	TNNP	25 083		25 083	13 289		13 289
4	Crown	-	9 434	9 434	-		-
	Price	39 456	33 532	72 988	8 023		8 023
5	Crown	69 225	12 818	82 043	7 030		7 030
	Bowaters	41 930		41 930	9 678		9 678
	Price	38 967		38 967	1 844		1 844
6	Bowaters	54 045	30 072	84 117	33 340		33 340
	Price	20 386		20 386	5 840		5 840
7	Crown	25 263		25 263	20 450		20 450
	Bowaters	16 723		16 723			
8	Crown	43 358	8 255	51 613	24 629		24 629
	Bowaters	12 023		12 023	881		881
	Price		3 192	3 192			
9	Crown	32 236	2 752	34 988	13 956		13 956
	Bowaters		9 830	9 830	10 685		10 685
	Price				253		253
10	Bowaters	942		942	980		980
	Price	31 522	2 205	33 727	31 120		31 120
11	Price	69 462	33 934	103 396	82 371		82 371
12	Price	28 005	10 042	38 047	13 493		13 493
13	Price	1 369		1 369			
14	Crown	5 193	7 472	12 665	5 915		5 915
	Bowaters	12 006	4 541	16 547	12 029	2 449	14 478

Cont'd...

Table 8 - Concluded.

Manage- ment unit no.	Ownership	Areas of moderate and severe defoliation (hectares)			Areas of moderate to high hazard (hectares)		
		Based on egg-mass survey	Change based on overwintering larval survey	Total area	Based on egg-mass survey	Change based on overwintering larval survey	Total area
15	Crown		1 095	1 095	4 315		4 315
	Bowaters		18 554	18 554	2 603	3 935	6 538
16	Crown				881		881
	Bowaters	1 102	1 353	2 455	2 091		2 091
18	Crown		431	431			
	Bowaters		2 010	2 010			
	GMNP				275		275
All	Crown	346 953	42 545	389 498	126 725		126 725
	Bowaters	138 771	66 360	205 131	72 287	6 384	78 671
	Price	229 167	82 905	312 072	142 944		142 944
	GMNP				275		275
	TNNP	25 083		25 083	13 289		13 289
	Private						
Total Island		739 974	191 810	931 784	355 520	6 384	361 904
Total Island (areas in acres)		1,828,513	473,974	2,302,485	878,507	15,776	894,285

There were 854 locations sampled on the Island and 51% had no egg-masses compared to 31% of 919 locations in 1977 (Table 9). The distribution of egg-mass sample points by predicted defoliation classes and geographical regions for 1977 and 1978 is shown in Table 9.

The average egg-masses per 10 m<sup>2</sup> of foliage for each sample point was grouped and analyzed for regional differences. Results for the total survey area and for each of the three regions for the past two years are reported in Table 10. A comparison of the average egg-mass counts from 1977 and 1978 showed a decrease in the western and eastern regions. The central region had only a slight decrease in egg-mass counts and was classified as unchanged. The decreases in egg-mass counts probably resulted from insect population stress owing to the poor condition of balsam fir in the west and the higher percent of the less susceptible black spruce and extreme budworm population in the east. It should be noted, that comparison of regional means without consideration of variation and range of data and tree conditions may lead to erroneous interpretation.

The favorable weather condition combined with sufficient food source (new growth) in some places resulted in an increase in the number of eggs per mass from that of 1977. During a special egg-mass survey (using unhatched eggs) collections were made at Bellevue, Random Island, Gambo, Baie Verte, Barry Brook, Aspen Brook Park, Deer Lake and Barachois Pond Park. These collections revealed that the average number of eggs per mass ranged between 9.8 and 28.6 depending on location, and the Island-wide average was 23 versus 16 eggs per mass in 1977.

#### b. Overwintering Larval Survey

The overwintering larval survey normally conducted in early spring was undertaken in November and December 1978. The data from this survey were used to check and refine the results of the egg-mass survey, for a more accurate forecast of population and defoliation. The overwintering larvae were extracted by the washing method of Miller et al. (1971) and populations were expressed by the rating established in New Brunswick (Miller and Kettela 1972) and adopted by Maine, United States (Table 11).

A total of 197 locations were sampled on the Island and 17 locations in Labrador. Results showed 60 points with extreme, 55 with high, 53 with moderate and 28 with low expected budworm populations for 1979 (Table 12). The mean larval counts in the three regions (west, central and east) were in the extreme category.

Table 9. Distribution of egg-mass sample points by predicted defoliation classes and geographical regions, 1977 and 1978.

Year sam- pled	Region <sup>1</sup>	No. points sampled	Distribution of sample locations in the predicted defoliation classes			
			0	light	moderate	severe
1977	W	432	165(17.4) <sup>2</sup>	157(16.5)	52(5.5)	58( 6.1)
	C	315	68( 7.2)	108(11.4)	42(4.4)	97(10.2)
	E	172	47( 5.0)	38( 4.0)	11(1.2)	76( 8.0)
	Labrador	31	19( 2.0)	8( 1.0)	2(0.2)	2( 0.2)
Grand total		950	299(31.6)	311(32.7)	107(11.3)	233(24.5)
1978	W	393	295(33.9)	70( 8.0)	20(2.3)	8( 0.9)
	C	301	100(11.5)	105(12.1)	34(3.9)	62( 7.1)
	E	162	40( 4.6)	44( 5.1)	24(2.8)	54( 6.2)
	Labrador	15	11( 1.2)	3( 0.3)	1(0.1)	0
Grand total		871	446(51.2)	222(25.5)	79(9.1)	124(14.2)

<sup>1</sup>W = western Newfoundland, C = central Newfoundland, E = eastern Newfoundland.

<sup>2</sup>Percentages in brackets are based on total number of sample points.

Table 10. Results from the 1977 and 1978 spruce budworm egg-mass surveys.

Region	No. of samples	Mean number of egg-mass per 10 m <sup>2</sup>						
		1977			1978			
		Mean	S.D.	Range	No. of samples	Mean	S.D.	Range
Western	432	92	181	0-1559	393	29	82	0-575
Central	315	204	296	0-2178	301	138	242	0-2255
Eastern	172	412	654	0-5080	160	192	243	0-1120
All	919	236			854	120		

Table 11. Density of overwintering spruce budworm larvae and infestation levels per 100 sq. ft. and per 10 m<sup>2</sup> of branch surface (after Stark 1978).

Overwintering larvae		Infestation level	Expected defoliation (%)
per 100 sq. ft.	per 10 m <sup>2</sup>		
0	0	Nil	0
1-100	1-108	Low	1-30
101-300	109-323	Medium	31-65
301-650	324-700	High	66-90
651+	701+	Extreme	90-100

Table 12. Distribution of overwintering larval sample points by predicted defoliation classes and geographical regions.

Regions	No. of points sampled	Predicted defoliation for 1979				
		Nil	Low	Moderate	High	Extreme
Western	69	0	24	28	8	9
Central	87	1	2	18	31	35
Eastern	41	0	2	7	16	16
Island	197	1	28(14)*	53(27)	55(28)	60(31)
Labrador	17	2	14(82)	1(6)	0	0

\* Figures in brackets are percent of total sample points.

The results indicated that the budworm infestation was essentially as predicted from the egg-mass survey except for an increase in the area of moderate to severe defoliation category by 192 000 hectares (474,000 acres) for an overall total of 932 000 hectares (2,303,000 acres) (Table 8 and Figure 6). These increases in population levels in the central and eastern regions of the Island were attributed to budworm dispersal from areas with high populations. In western Newfoundland in most of the additional areas, including the largest one at Glide Lake, more intensive sampling and larval dispersal were just sufficient to cause a change from low to moderate and from moderate to severe defoliation categories.

c. Tree Condition

Concurrent with the collection of egg-mass samples, a survey of tree condition in the infested area was also made. At each egg-mass sample point, the following data were taken from 10 balsam fir or spruce trees: percent defoliation of current year's growth, percent old or previous defoliation to the nearest 10%, estimate of tree vigor and egg-mass population. These data were used to determine the general state of the stands. Stand condition data in conjunction with the egg-mass and overwintering larval survey data and damage assessment were then used in the determination of hazard values and potential damage to fir-spruce stands in the absence of control measures and the collapse of budworm population. Guidelines for determining tree conditions are presented in Table 13.

d. Hazard

Results from the egg-mass, overwintering larval and tree condition surveys were used to establish a hazard rating for each sample point. The hazard rating system and relative values are summarized in Table 14. For the first time in Newfoundland, total hazard values were determined for each sample point and were plotted on a map to delineate budworm hazard areas.

The hazard ratings were interpreted as:

1. Very high - tree mortality and extensive top-kill is expected.
2. High - tree vigor will be reduced and top-killing is expected.
3. Low to moderate - tree more or less in fair condition. A high insect population is present. Tree vigor will be reduced and top-killing may occur in scattered locations.

In 1979, based on the egg-mass survey, it was forecast that moderate to high hazard with high insect population levels would exist on 356 000 ha (879,000 acres) (Table 8 & Figure 7). Based on the overwintering larval survey, the forecasted area of moderate to high hazard has increased

Table 13. Guidelines and relative numerical values of tree conditions used to arrive at hazard ratings in conjunction with tree damage and spruce budworm population levels (after Miller and Kettela 1975).

Current Defoliation Guidelines and Categories

<u>Category</u>	<u>% defoliation</u>	<u>Category</u>	<u>% defoliation</u>
0	0	5	46-55
T	1-5	6	56-65
1	6-15	7	66-75
2	16-25	8	76-85
3	26-35	9	86-95
4	36-45		
10a	96-100	Needles almost all missing but some shoot axils remaining.	
10b	96-100	Nearly all needles and shoot axils destroyed.	

Previous Defoliation Guidelines and Categories

<u>Category</u>	<u>% defoliation</u>	<u>Damage</u>
0-Zero	0	No apparent damage except to current year's foliage.
L-Light	1-25	Some defoliation evident on previous growth, particularly on previous year's growth. No bare top.
M-Moderate	26-75	Thin crown, short bare top, defoliation evident on at least two previous year's twigs.
S-Severe	75-100	Marked defoliation on two or more year's growth; crowns thin and grayish in appearance and frequently two or more feet of bare top.

Damage: Dead tops, record percentage of trees with dead tops. Dead trees, record percentage of dead trees.

Tree Vigor

- G - Current foliage apparently normal or nearly normal. Trees evidently capable of rapid recovery.
- F - Shoot production moderately affected, obviously less vigor but with evidence of ability to recover.
- P - Current shoots present but sparse. Tree clearly demonstrating serious deterioration of growth capability.
- N - Dying. No old foliage, few current or adventitious shoots.

Table 14. Hazard rating system used in 1978 to forecast expected losses in spruce budworm infested areas (stands) (after Miller and Kettela 1975).

1. Current Defoliation

<u>Tally Code</u>	<u>% defoliation</u>	<u>Hazard rating</u>
0	0	0
T-2	1-25	1
3-6	26-65	2
7-10a	66-95	3
10b	96-100	4

2. Old Defoliation or Previous Damage

<u>Tally Code</u>	<u>Hazard rating</u>
0-Zero	0
L-Light	3
M-Moderate	6
S-Severe	9
Dead tops	12
Dead trees	15 (optional)

3. Tree Vigor

	<u>Hazard rating</u>
N-Dying	0
P-Poor	-1
F-Fair	-2
G-Good	-3

4. Egg-mass/10 m<sup>2</sup> of foliage

<u>Tally Code</u>		<u>Expected defoliation %</u>	<u>Hazard rating</u>
0	Nil	0	0
1-106	Light	1-30	1
107-257	Moderate	31-65	2
258-429	High	66-90	3
430+	Very high	91-100	4

5. Sample point hazard rating categories for the Newfoundland Forest Research Centre.

<u>Hazard rating</u>	<u>Range of total values</u>	<u>Remarks</u>
Low	0-6	
Moderate	7-10	
High	11-14	Protection suggested
Very high	15+	Presalvage suggested

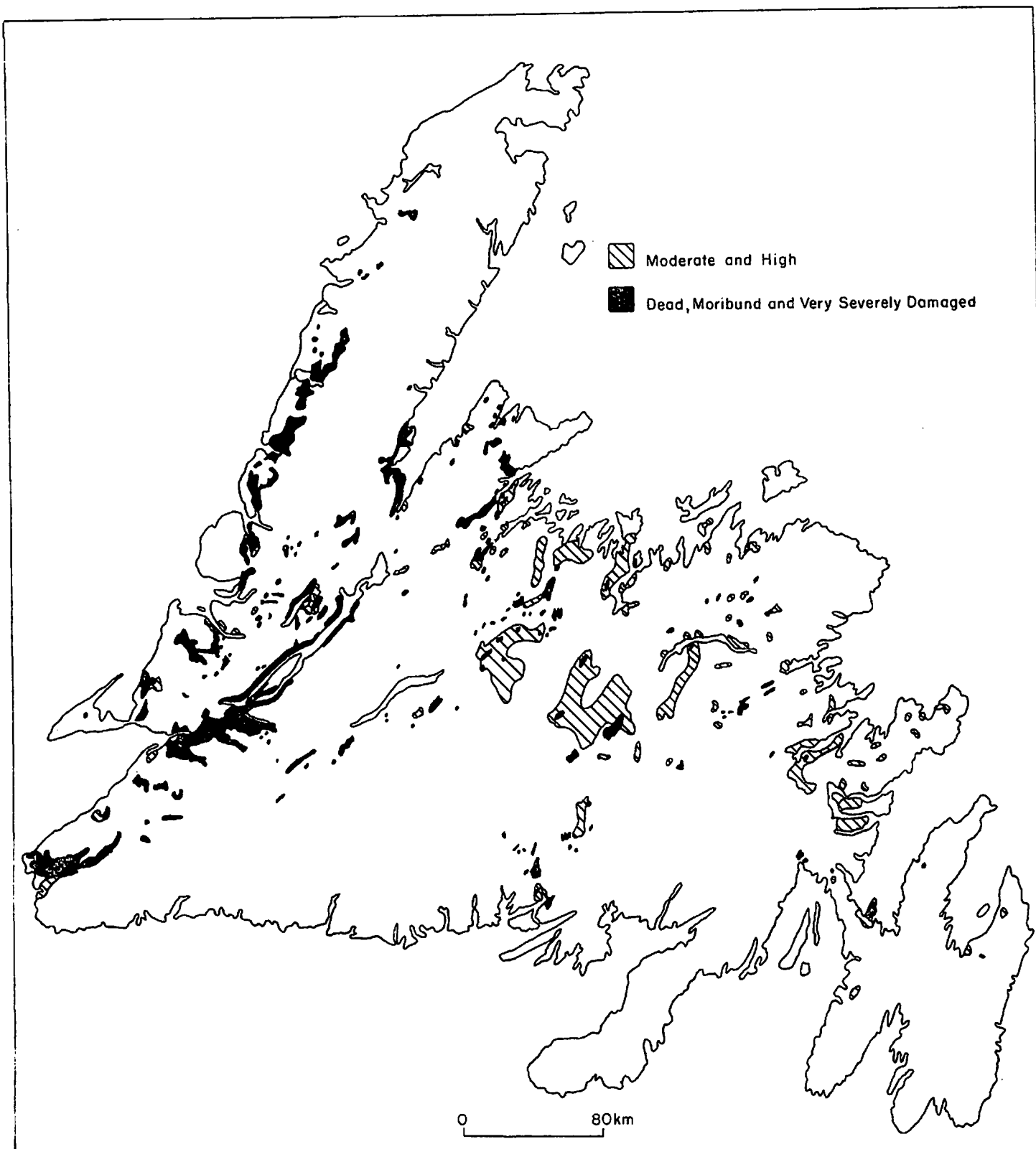


Figure 7. Areas of dead, moribund and very severely damaged stands and forecast of moderate and high hazard areas with high populations for 1979.

by 6 000 hectares (16,000 acres) for a total of 362 000 hectares (895,000 acres). These high hazard stands were distributed predominantly in central and eastern Newfoundland. The 300 000 hectares (742,000 acres) of stands already in the dead, moribund and very severely damaged classes were rated in the very high hazard category. Most of these stands were forecast to have very low budworm population levels. Therefore, foliage protection would have little meaning and salvage or pre-salvage was recommended.

The present spruce budworm outbreak has had a serious economic impact on the forest resources in Newfoundland. Munro *et al.* (1979) have quantified economic impacts for damage incurred to 1978; this amounted to over \$25.7 million and included costs for losses of wood volume in standing dead timber and growth, disruption of normal logging operations, increased costs of harvesting and processing damaged timber, spraying operations, damage assessment surveys and research. If the possible cost of forest rehabilitation was included, the overall estimate of impact would be \$48.1 million.

Even more important is the probable serious effect of the outbreak on the continuity of wood supply in the near future. The level of disruption will depend on past damage and to a considerable extent on the degree of protection provided to stands in the moderate to high hazard category. As accumulation of damage continues, the need for more intensive damage assessment and for economic analysis of the impacts on the forest resource and on the wood supply for the mills, is becoming more essential.

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