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Results of aerial spraying in 1972 and 1973 to control the eastern hemlock looper (*Lambdina fiscellaria fiscellaria (Guen.)*) on Anticosti Island

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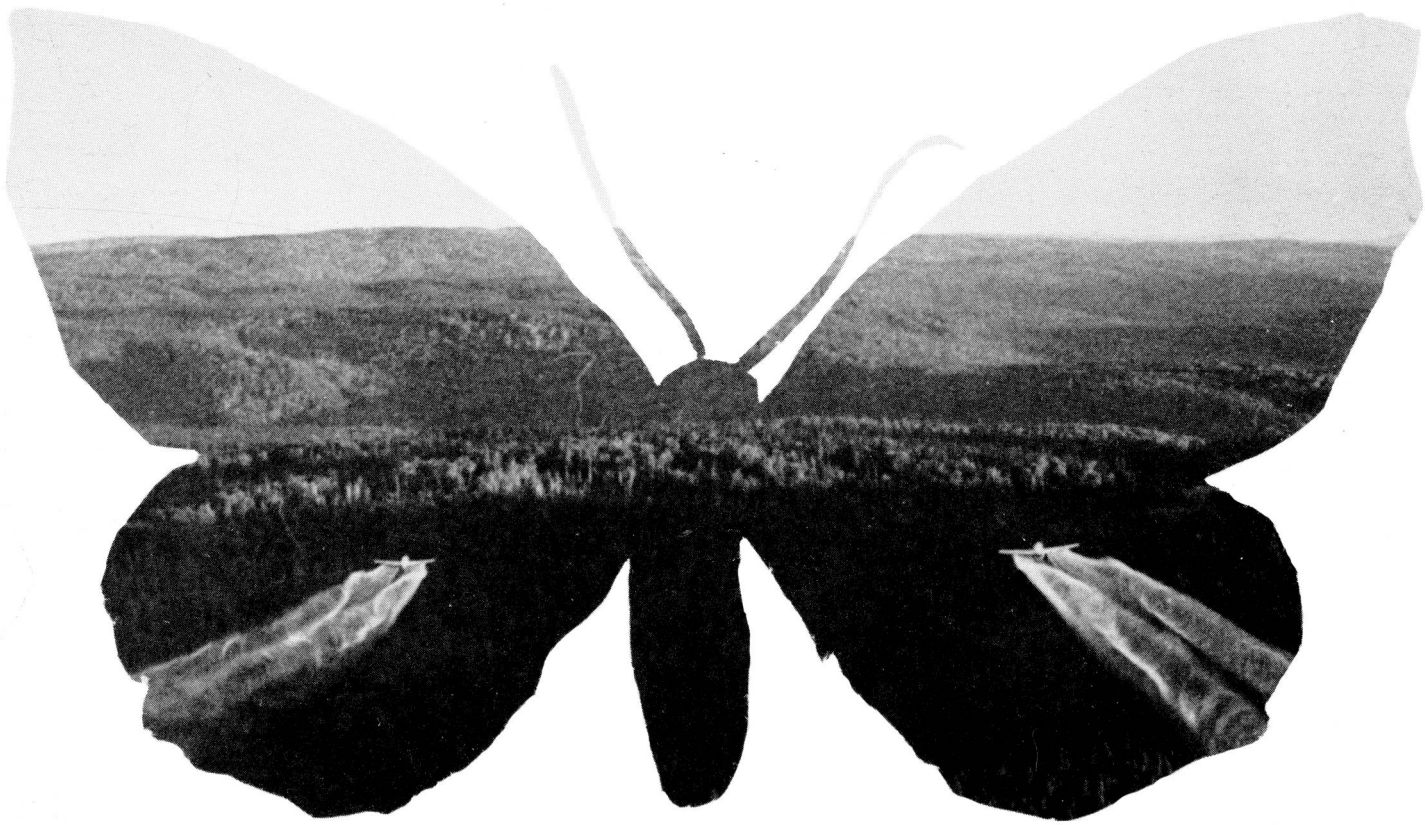

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RÉSUMÉ

Une diminution de 85% des populations larvaires de l'arpenteuse de la pruche,(*Lambdina fiscellaria fiscellaria* (Guen.)) fut obtenue sur environ 80% du territoire traité à l'insecticide fenitrothion à l'île d'Anticosti en 1972. Aucune défoliaison ne fut signalée sur 90% de la superficie traitée et 10% des sapinières ayant reçu le traitement furent endommagées. En 1973, le programme de répression de l'arpenteuse de la pruche à l'île d'Anticosti comprenait le traitement de 16 900 ha; une mortalité larvaire de 96,6% et 97,5% était observée dans les secteurs ayant reçu une et deux applications d'insecticide respectivement. Aucune défoliaison ne fut signalée dans 75% du secteur traité et une défoliaison légère à modérée fut observée sur 1 023 ha. L'action jumelée du traitement à l'insecticide et d'un entomopathogène appartenant au genre *Entomophthora* a été la cause principale qui mit fin à la pullulation de l'arpenteuse de la pruche à l'île d'Anticosti.

En 1971, des inventaires aériens et terrestres de l'île d'Anticosti démontraient qu'une importante pullulation de l'arpenteuse de la pruche avait endommagé 226 629 ha de forêt et que les sapinières étaient en grande partie détruites sur une superficie de 84 986 ha. L'insecte s'était également manifesté dans plusieurs sapinières, d'une superficie totale évaluée à 71 226 ha localisées sur la Côte-Nord plus particulièrement près de Havre-Saint-Pierre et dans le bassin des rivières Aguanus et Natashquan. Dans le but de protéger les peuplements de sapin de l'île d'Anticosti et de la Côte-Nord menacés de destruction par l'arpenteuse de la pruche en 1972, le ministère de l'Energie et Ressources du Québec, en collaboration avec la compagnie Consolidated-Bathurst Inc. et le Service canadien des forêts, élabora un projet de traitement à l'insecticide de 214 488 h à l'île d'Anticosti et 71 226 ha sur la Côte-Nord.

Le traitement de 1972 à l'île d'Anticosti eut lieu entre le 3 et le 12 juillet à l'aide de 15 avions TBM Avenger. Une double application d'insecticide, à un intervalle de 4 à 8 jours, fut réalisée à raison de 1 461 L/ha (140 6 g/ha d'ingrédient actif). A la suite du déclin naturel des populations de l'insecte sur la Côte-Nord le programme de traitement à l'insecticide envisagé fut annulé. Le programme de 1973 comprenait le traitement de 16 900 ha à l'aide du même insecticide qu'en 1972; seulement 4 180 ha furent traités suite au déclin prononcé des populations de l'insecte. Ce rapport renferme des observations sur la biologie de l'arpenteuse de la pruche ainsi qu'une description des méthodes utilisées pour estimer les populations d'oeufs, de larves et d'adultes de l'insecte.

ABSTRACT

An 85% reduction in larval population of the eastern hemlock looper (*Lambdina fiscellaria fiscellaria* (Guen.)) was achieved over 80% of the area treated with fenitrothion in 1972 on Anticosti Island. No defoliation occurred on 90% of the treated area with light to severe defoliation on the remaining 10%. The 1973 spray program covering 16 900 ha resulted in high larvai mortality in the area treated once (96.6%) or twice (97.5%). Seventy five per cent of the sprayed area was not defoliated and 1 023 ha suffered light to moderate defoliation. The combined action of aerial spraying and of an *Entomophthora* fungi were responsible for bringing the eastern hemlock looper outbreak on Anticosti Island to an end.

Aerial and ground surveys on Anticosti Island in 1971 showed that defoliation by the eastern hemlock looper had occurred on 226 629 ha and tree mortality on 84 986 ha in mature balsam fir stands. An outbreak of this pest also occurred on 71 226 ha on the Lower North Shore of the Gulf of St. Lawrence near Havre-Saint-Pierre and in the Aguanus and Natashquan river watersheds. The Québec Department of Energy and Resources and the Consolidated-Bathurst Company agreed to spray to protect balsam-fir stands from further damage on Anticosti Island and the North Shore. The Laurentian Forest Research Centre measured hemlock looper populations levels prior to spraying, determined timing of spray and assessed results. About 214 488 ha on Anticosti Island and 71 226 on the North Shore were to be sprayed. Two applications of fenitrothion (with intervals of 4 to 8 days) at the rate of 1 461 L/ha (140 6 g/ha of active ingredient) were recommended. The spray operation on Anticosti Island was carried out in 1972 between July 3 and 12 using 15 TBM Avenger aircrafts. The same insecticide and dosage rate were recommended for the 1973 spraying program of 16 900 ha; only 4 180 ha were treated using a CL-215 aircraft. The 1972 spray program on the North Shore was cancelled following collapse of the infestation.

Notes on the life history and sampling methods to monitor hemlock looper egg, larval and moth populations are presented.

INTRODUCTION

The hemlock looper (*Lambdina fiscellaria fiscellaria* (Guen.)) is one of the most harmful insects attacking balsam fir (*Abies balsamea* (L.) Mill.) stands in eastern Canada because trees die within a year after infestation. Six hemlock looper outbreaks have been reported in Quebec since the 1920s (Benoit and Desaulniers 1972).

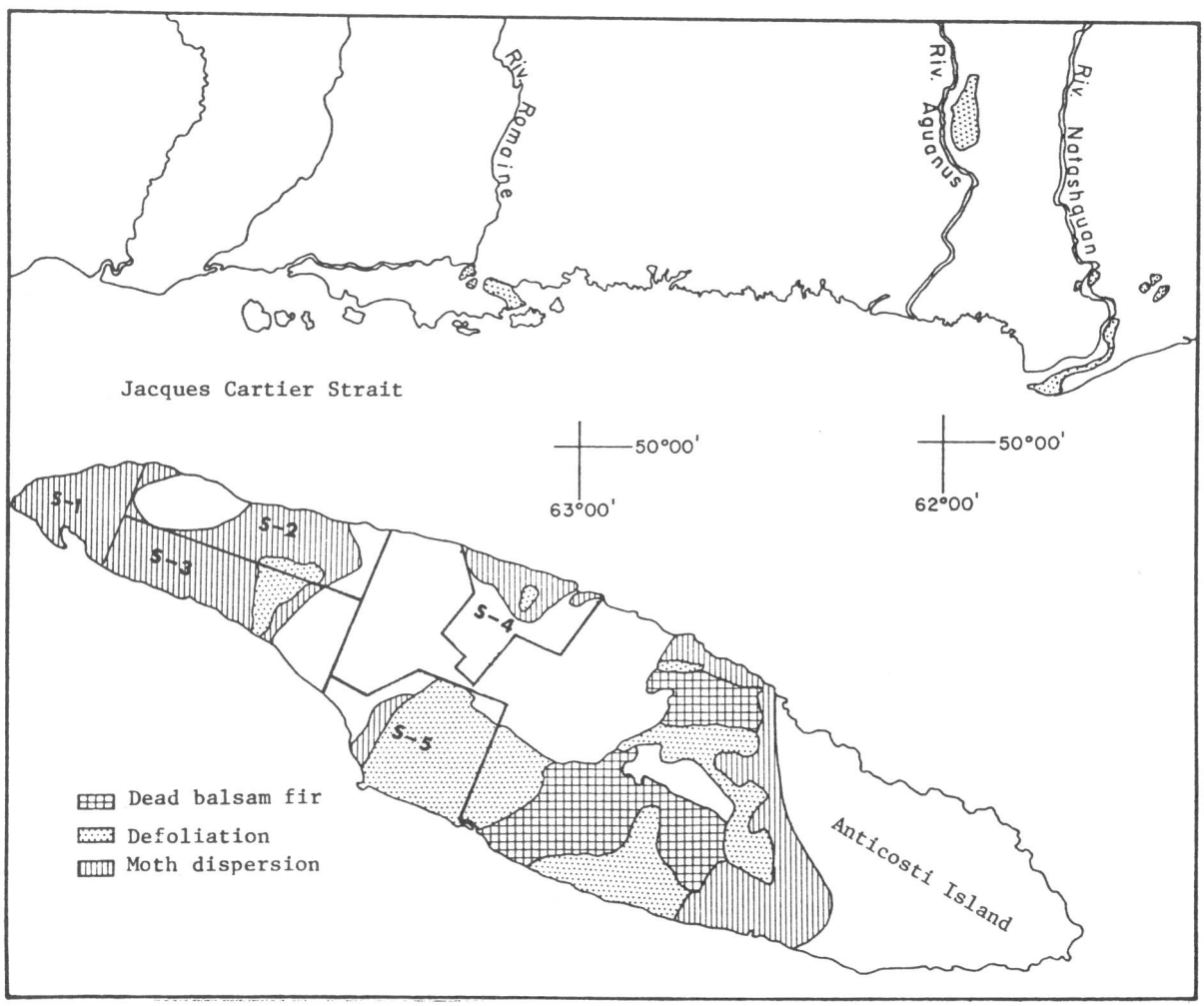

Figure 1. Area of eastern Quebec infested by hemlock looper in 1971. Five sectors to be sprayed on Anticosti Island in 1972.

To protect balsam fir stands on Anticosti Island and Quebec's North Shore from destruction, the Québec Department of Energy and Resources, Consolidated-Bathurst Inc. and the Canadian Forestry Service developed a chemical control program to be implemented over 214 488 ha on Anticosti Island and 71 226 ha on the North Shore (Figure 3).

This report includes a description of the life history and habits of the hemlock looper; the spray program; and the effectiveness of spraying.

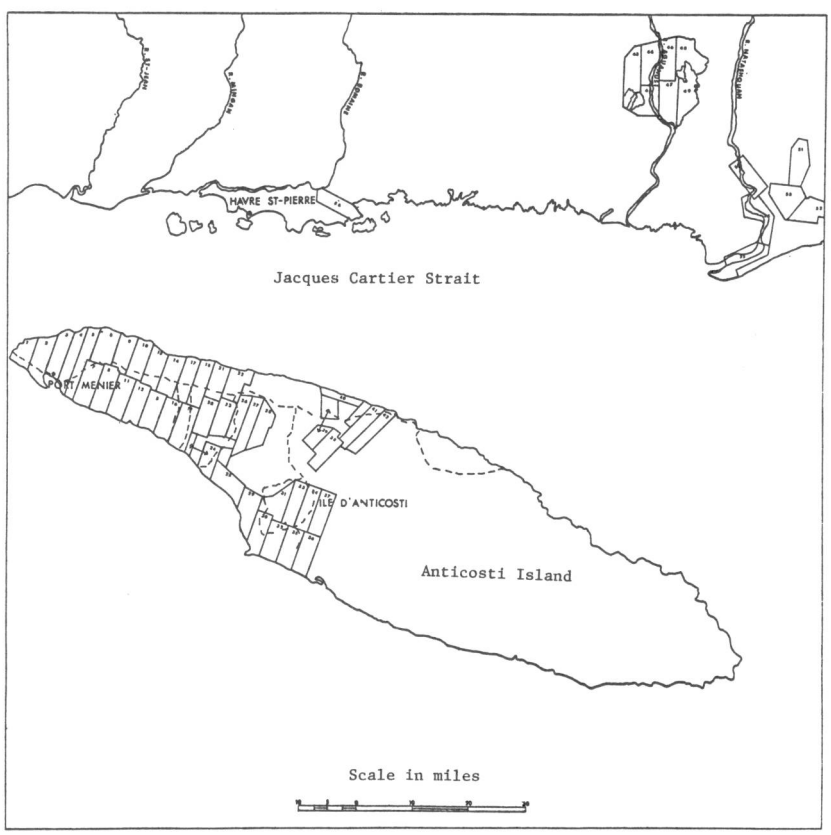

Figure 3. Forty-two blocks of 5 100 ha each sprayed in 1972 on Anticosti Island and Québec's North Shore.

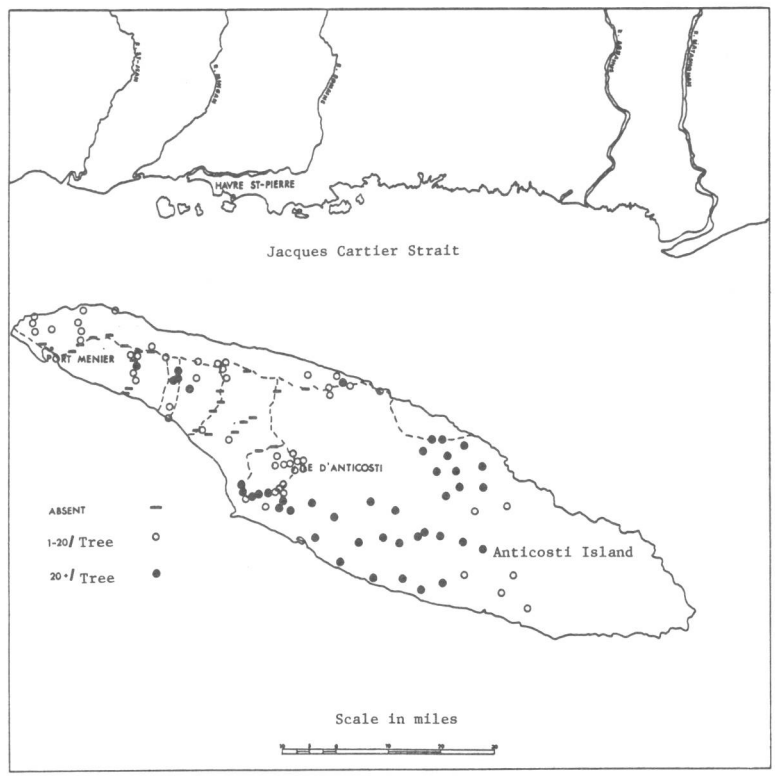

Figure 2. Distribution of hemlock looper adults, September 1971.

Four larvae were found per sampling in surveys conducted on Anticosti Island in 1970 and an outbreak was not foreseen on the island for the near future. However, in July 1971 the fire warden at the Jupiter River Lookout Tower reported that the forest was turning red. This change began in the east and was progressing westward. Aerial and ground surveys showed that the density of hemlock looper populations had reached levels damaging 226 630 ha of balsam fir stands to varying degrees: light defoliation, 44 515 ha; moderate defoliation, 4 050 ha; severe defoliation, 93 080 ha; and destroyed stands, 84 985 ha (Figure 1). In autumn 1971, hemlock looper adults were found (Figure 2) on 178 065 ha beyond previously infested areas. A fall survey of Quebec's North Shore showed that the hemlock looper had defoliated and killed trees on 16 188 ha, near Havre-Saint-Pierre and in coniferous stands in the Aguanus and Natashquan River watersheds (Figure 1).

red. Signs of infestation appear as the larvae develop through the second and later instars. Defoliation is observed particularly after mid-July. Older larvae eat only part of the needle resulting in reddening and rapid browning of entire trees in areas where insect populations are high. Damaged needles usually fall in August and September, but may remain on the tree throughout the winter.

Rain, wind, parasites or lack of food, sometimes cause larvae to gently lower themselves on silken threads to the ground. During periods of abundant rainfall, larvae suspend themselves a short distance below fir branches and wait until conditions favour their development.

Pupae

Newly formed pupae vary from greyish-brown to dark brown (Figure 4-4) and average 13.5 mm in length. Pupation is first observed in early August; by early September, nearly all larvae populations are in the pupal stage. The pupal stage lasts an average of seventeen days. Pupation sites include lichens and mosses often found on tree trunks, as well as bark crevices, stumps and old decaying tree trunks.

Adults

Adult moths forewings span about 32 mm and vary from creamy tan to brownish-grey, with two irregular purple-brown transverse lines (Figure 4-1) and only one such line on the hind wings. Adults generally emerge in late August and the peak is reached the first or second week of September. If new pupae are present in early September flying will end late in the same month. Adult moths are poor fliers. They are active mostly in late afternoon, especially on hot, sunny days. Unlike their male counterparts, female moths are inactive and are found mainly on the trunk and branches of the host; when disturbed, they drop to the ground a short distance from the tree.

CHARACTERISTICS OF HEMLOCK LOOPER OUTBREAKS

In Newfoundland, hemlock looper infestations last from five to seven years, with local outbreaks of approximately two years and latency periods from three to five years. Outbreaks generally begin in several infestation sites

DESCRIPTION, LIFE HISTORY AND HABITS OF THE HEMLOCK LOOPER

Detailed knowledge of the life history of a forest insect is a pre-requisite to planning and conducting any successful control operation. Details of the life history of the eastern hemlock looper have been documented by several authors: in Ontario by de Gryse and Schedl (1934), in Quebec by Watson (1934), in Newfoundland by Carroll (1956). Watson's (1934) observations of the 1928-29 outbreak on the North Shore are too fragmentary and general to be used as a basis in planning biological studies.

Eggs

Hemlock looper eggs are oval and approximately 0.95 mm long (Figure 4-2). Pale green when first laid, eggs normally turn copper-brown a few weeks later but remain green if sterile. They turn black a few weeks before hatching if parasitized. Oviposition begins during the third week in August and ends approximately three weeks later. Eggs are deposited singly or in groups of two or three. The egg is the insect's overwintering stage. According to the above authors, weather considerably influences site selection during oviposition. During windy, cool, moist periods, eggs are laid at ground level or in the shrub layer, but during calm, warm periods they are deposited on the trunk and crown of host and other trees. Hemlock looper egg population sampling in various infested areas of Anticosti Island in the spring of 1972 showed that, in 1971, eggs were primarily laid among lichens growing in abundance on the trunk and branches of balsam firs. In 1972, hatching began on June 10, reached its peak the last week of June, and ended early in July.

Larvae

The hemlock looper goes through four larval instars (Figure 4-3) over a period of approximately fifty days. When hatched, larvae are dark grey with black transverse bands. In later instars, larvae vary from greyish-brown to greenish-brown. Full grown larvae are approximately 31 mm long.

Young larvae feed on a variety of plants but survive best on the new needles of balsam fir; damage to foliage is observed when new needle tips turn

which are often scattered over a vast area. The infested areas increase and original infestation sites spread. Often these scattered infestations coalesce forming a large irregular outbreak. Individual local infestations usually collapse after one or two years. Mature or overmature balsam fir stands are most susceptible to hemlock looper outbreaks (Otvos 1973).

Anticosti Island

By 1971 the hemlock looper outbreak on Anticosti Island and Quebec's North Shore had reached considerable proportions, making it difficult to pinpoint when it began or its development. However, based on Otvos *et al.* (1971) data for Newfoundland and our observations of the 1972 Anticosti Island outbreak, these latter infestations appear to have begun in 1970 in restricted areas on the eastern part of the island, also in the south central region and in the northern sector between Observation and Natiscotec Rivers. The outbreak progressed very rapidly in 1971 and damage to trees was observed on 226 629 ha; severe defoliation and/or high tree mortality occurred on 84 986 ha (Figure 1). Stands were severely defoliated east of Brick River to Chaloupe River, and on the northern region of the island between Vauréal and Natiscotec Rivers.

Coniferous stands suffering light to moderate defoliation were: west of Brick River; inland around the Jupiter River watershed; in the southern region between Sainte-Marie and Cailloux Rivers; and in the Macdonald River watershed to the north. In the last three watersheds hemlock looper larval populations were of recent origin (1971). In 1972, restricted outbreaks appeared in a sector near Baleine Creek and in the west between Lake Plantain and Lake Whitehead. On Anticosti Island the hemlock looper outbreak seems to have spread from east to west.

Initial infestations collapse in one or two years. This rapid decline in populations can be attributed to adverse weather conditions or food shortage following complete defoliation of host trees. In 1972 insect populations completely disappeared in areas that suffered severe defoliation the previous year. Parasites, predators, and disease also contributed to insect mortality helping the rapid decline of looper populations. However, these biotic factors come into play only near the end of the outbreak.

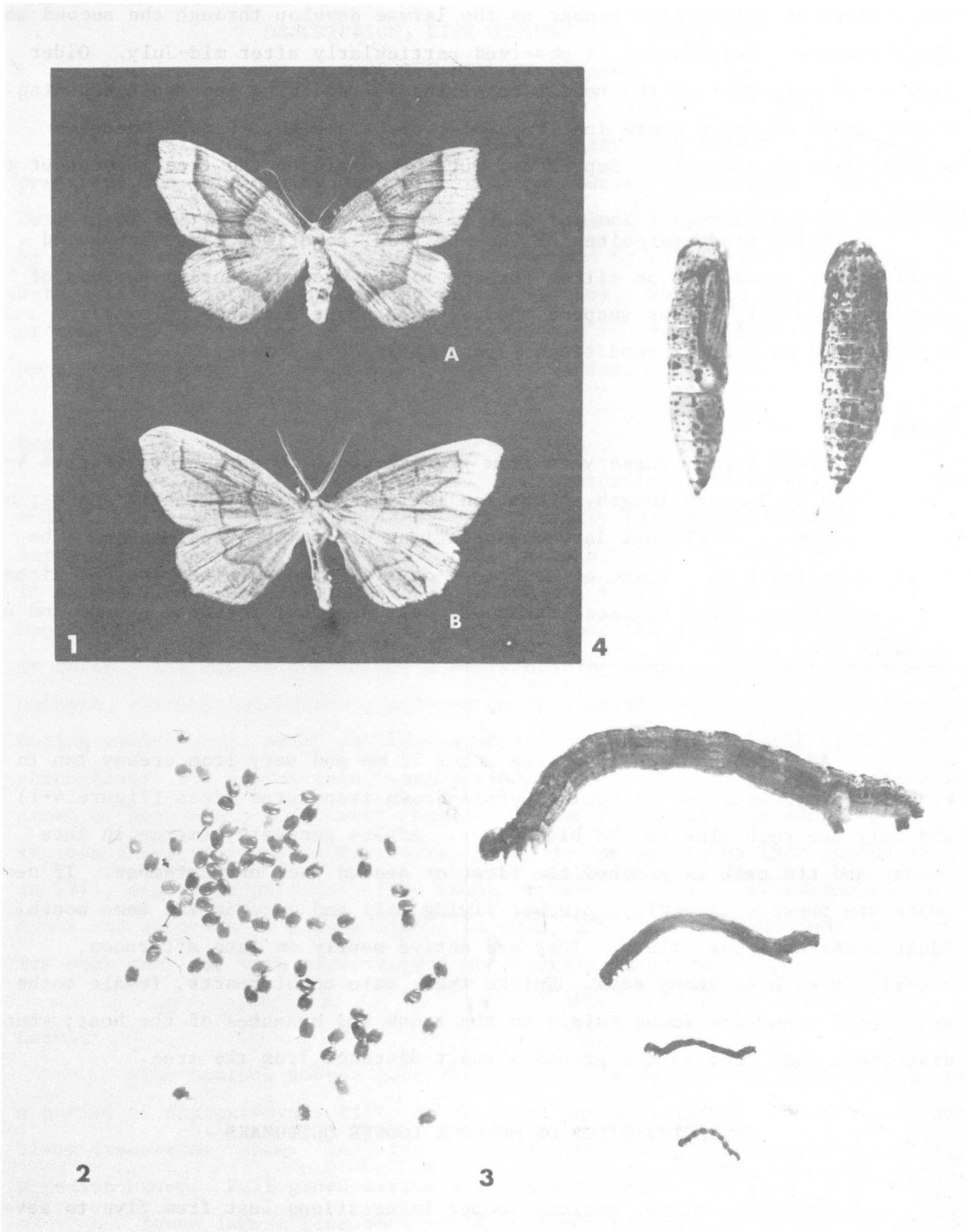

Figure 4. The hemlock looper life history: 1) adults; female (a) male (b), 2) eggs, 3) larvae, 4) pupae.

The North Shore outbreak was chiefly characterized by the high number of stands attacked, the wide variations in stand size from a few hectares to 100 ha, and their distribution over a vast territory. There seemed to be a relation between the size of the areas defoliated and the proportion of balsam fir to deciduous trees.

The North Shore looper outbreak occurred on balsam fir located in black spruce stands scattered over a wide area (63% of all forest vegetation is black spruce, Forest Survey Division, Québec Department of Energy and Resources). This forest was broken up by numerous extensive peatlands, rock outcroppings and many lakes and rivers. Three infested stands covering 3 238 ha were located at Mont Sainte-Geneviève near the shoreline, in about twenty small infestations of a few hectares to 100 ha near large inland bodies of water such as Lake Victor and Lake Kégashka, or along the banks of the Natashquan River. The hemlock looper caused damage or mortality in balsam fir stands of the co-dominant or suppressed classes.

The abundance of black spruce stands, which are not vulnerable to attack by the hemlock looper, and the absence of large balsam fir stands were the main reasons for the rapid decline of the looper outbreak on the North Shore.

EVENTS LEADING TO THE SPRAY PROGRAM

Survey of infested areas

At the request of Consolidated-Bathurst Inc., then owner of Anticosti Island, the Québec Department of Energy and Resources carried out defoliation and hemlock looper moth population surveys during the summer of 1971. Defoliation had occurred on 226 030 ha and moths were observed on an additional 178 070 ha (Figures 1 and 2). Approximately 214 500 ha were to be sprayed on Anticosti Island in 1972.

The 16 188 ha infested on the North Shore near Havre-Saint-Pierre, Aguanish and Natashquan were to be sprayed from an operational base at Havre-Saint-Pierre Airport. Three TBM Avenger aircrafts from the Anticosti Island spray program would carry out the planned spraying.

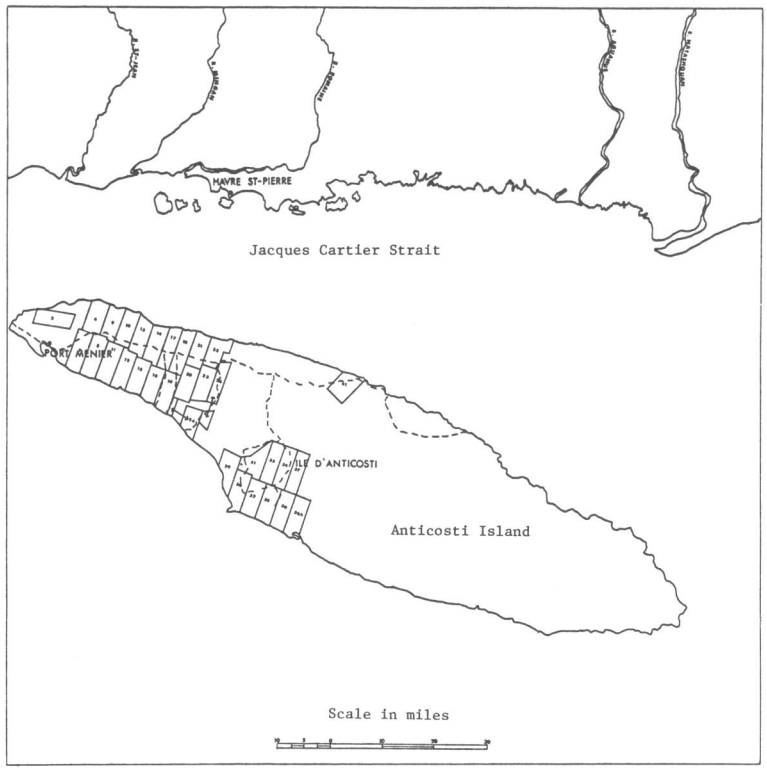

Figure 5. Pre-spray sampling areas of hemlock looper larval populations, 32 blocks of 5 100 ha each.

North Shore

The 1971 hemlock looper outbreak on Québec's North Shore (Figures 1 and 3) covered 16 188 ha of balsam fir stands in three different areas: Mont Sainte-Geneviève, near Havre-Saint-Pierre; the Natashquan River watershed and a few stands near Lake Kégashka; and a few stands between the Aguanus River and Lake Victor.

Ground and aerial surveys carried out in late September 1971 showed the presence of adult loopers, severe defoliation, and tree mortality in balsam fir stands in the Natashquan River watershed. This damage occurred in narrow, irregular bands separated by stands of deciduous trees, extending 30 km along the river bank. A few stands of young balsam fir, near Lake Kégashka, were also destroyed.

It was decided to spray two applications of fenitrothion, at a rate of 1 461 L/ha. Forest Protection Limited would subdivide the area into rectangular blocks of 5 100 ha each, mix insecticide and carry out aerial spraying operations. Port-Menier (Anticosti Island) and Havre-St-Pierre (North Shore) airports were to be used as bases for aerial spraying.

1972 AERIAL SPRAYING

Monitored area

To ensure proper distribution of tasks among members of the sampling team, as well as greater efficiency and better co-ordination of field work, the area to be sprayed on Anticosti Island was divided into five sectors (Figure 1) of forty-two blocks of 5 100 ha each (Figure 3):

Sector 1 (S-1): Blocks Nos. 1 to 5 inclusive.
Sector 2 (S-2): Blocks Nos. 6-9-10-13-14-17-18-21 and 22.
Sector 3 (S-3): Blocks Nos. 7-8-11-12-15-16-19-20-23-24-25-26 and 27
Sector 4 (S-4): Blocks Nos. 38-39-41 and 42.
Sector 5 (S-5): Blocks Nos. 29 to 37 inclusive.

Four teams of two persons each ground sampled the first four sectors. The fifth sector was sampled by helicopter by the technician from the Department of Energy and Resources. This technician was responsible for sampling blocks where ground access was impossible. A Laurentian Forest Research Centre technician sampled Sector 1; he also prepared a schedule of daily activities for the various teams and analysed the data they gathered.

Description and results of sampling

The results of research done in Newfoundland by Otvos *et al.* (1971) on hemlock looper sampling techniques to survey larval populations and damage were used in part to assess the effectiveness of spraying.

The following criteria were used to establish the boundaries: age and composition of stands, light to moderate defoliation, and moth population level.

The Québec Department of Energy and Resources requested the co-operation of the Canadian Forestry Service. Mr. G.L. Warren, Newfoundland Forest Research Centre, confirmed the accuracy of defoliation surveys and suggested further studies in spring 1972 to precisely define infested areas and looper population levels. He also suggested the formation of a committee to plan the spray program and to co-ordinate the various activities leading to aerial spraying.

Spray program co-ordinating committee

The committee members, formed early in February 1972, were from the Conservation Branch of Québec's Department of Energy and Resources, the Laurentian Forest Research Centre and a representative of Consolidated-Bathurst Inc. The committee's primary role was to define the tasks and responsibilities of the agencies involved and to co-ordinate the various organizational stages of the planned spray program.

The agreements reached and responsibilities assigned during the first four meetings are summarized. Because of its goal to protect Quebec's forests, the Department of Energy and Resources agreed to pay two-thirds of the cost of spraying, to define the areas requiring protection, and to sign a contract with a firm specializing in aerial spraying. The Department also hired students, and guaranteed a technician to monitor looper populations, the availability of a helicopter and two vehicles for use by survey teams. Consolidated-Bathurst Inc. agreed to pay the remaining third, to assign a member of its staff to assist the person in charge of entomological studies, and to provide space for an operation control station. The Laurentian Forest Research Centre assigned one of its staff members, assisted by a technician, to direct survey teams, select sampling techniques, and evaluate the effectiveness of spraying. It also supplied two vehicles and survey equipment.

The co-ordinating committee's fifth and final meeting, April 12, 1972, was attended by representatives from the Chemical Control Research Institute of Canada, the Québec Department of Energy and Resources, Forest Protection Limited of New Brunswick, and the Laurentian Forest Research Centre.

counting larvae dislodged from branches in the lower half of the crown from one side of the tree; the unsampled side was used for post-spray larval population surveys. Branches were beaten with a 2.5 m pole to remove larvae. A rectangular sheet, 2.14 x 2.74 m, divided into nine equal rectangles, was placed beneath the sampled tree to gather and count larvae. When larvae exceeded one hundred, only those in the centre rectangle were counted and this figure was multiplied by nine.

The average larval population per sample plot was determined on the basis of populations observed on two sample trees, and the average population per 5 100-ha block was estimated from results for three sample plots. There were generally three sample plots per block, but this varied with larval population density; the number of sample plots was proportional to the population level in a given sector.

Pre-spray sampling began as soon as a sample plot with ten or more newly-emerged larvae per tree was discovered. This "significant number" represented the critical larval population level beyond which trees would be seriously damaged. If the larval population of at least one sample plot in a 5 100-ha block exceeded this number, spraying was recommended; if there were less than ten larvae per tree, the block was withdrawn from the spray program. The first larvae were observed in the MacDonald River area (Block No.41) on June 10, 1972. Ten days later, the critical level of ten larvae per tree was reported in stands near Baleine Creek.

The characteristics of coniferous stands in each of the five sectors, as well as pre-spray insect population levels are described below.

Sector 1

Sector 1 was composed almost entirely of 50 to 60 year-old white spruce originating from cutovers or forest fires. Mature stands were found on approximately 3 500 ha in the central region of Sector 1, between Lake Plantain and Lake Whitehead.

Egg population survey

This survey was carried out during the first two weeks of June 1972, to determine the looper's oviposition sites, to find out when hatching began and the hatching period, and to assess larval population levels. A square foot of moss (Bryophytes) and organic matter, as well as a piece of stump or tree trunk were selected beneath the conifer chosen; this was done in most blocks in each sector. The average height of the trees sampled was 12 m. Trees were felled and cut into four sections (trunk, lower, middle, and upper crown). A 40-cm log was taken from each of these four sections, and three branches from each of the three layers of the crown. A sample of lichens was gathered from each part of the tree until two or three plastic bags (15 x 38 cm) had been filled. These samples were examined in the laboratory to determine oviposition sites and the beginning and duration of hatching. In the laboratory, eggs began to hatch a few days after they were brought in and ended two weeks later.

Almost all eggs (98%) were deposited on host trees, and only 2% were deposited on old logs, stumps *etc.* on the ground. Ninety-nine percent were laid among lichens in the crown: 52% on the stem, 30% on the branches and 17% on twigs; 1% was laid among lichens on the trunk. The abundance of lichens in balsam fir stands was later taken into account in carrying out the egg population and pre-spray larval population survey.

Pre-spray larval population survey - Anticosti Island

The sampling techniques used to evaluate the pre-spray larval population levels were described by Otvos *et al.* (1971).

The larval development was studied to find out the number of larval instar and duration of larval development especially that of the first instar. The results were used to set the starting date for pre-spray surveys and subsequent sampling. Pre-spray sampling helped to establish the boundaries of the infested area requiring treatment, and to evaluate the effectiveness of spraying.

In each of the forty-two 5 100-ha blocks on Anticosti Island, three sample plots were established, each containing two balsam fir trees averaging 9 m in height. On each tree pre-spray larval population was estimated by

Sector 3

Except for a few black spruce stands between the Sainte-Anne and Loutre Rivers, and white spruce stands in part of the Fusil River watershed, Sector 3 was mostly mature balsam fir.

Results of surveys in fourteen blocks of this sector indicated relatively high looper populations, about 19 larvae per tree (Table 3). These results corroborated those obtained in the 1971 moth and defoliation surveys, which indicated that larval populations would be sufficiently high in 1972 to cause light to moderate defoliation. A highly infested area was found in Block 15.

Sector 4

This sector was composed of overmature coniferous stands located in the MacDonald River watershed. Moderate defoliation was recorded in this area in 1971. The area is bound on the east by a vast area destroyed in 1955 by a forest fire, on the south and southwest by black spruce stands, and on the west by an area where felling occurred from 1960 to 1971.

Table 2. 1972 pre- and post-spray larval populations in Sector 2 blocks and fenitrothion spraying dates.

Block No.	Pre-spray			Post-spray			Spraying				
							Hour				Interval
	Date of last sample	No. of larvae	Average larv. pop. per tree	No. of larvae	Average larv. pop. per tree	Total mortality rate (%)	1st am	1st pm	2nd am	2nd pm	(days)
6	30-05	42	7.0	1	0.1	98.6	6 -		12 -		6.0
9	1-07	29	4.8	0	0	100.0	- 5		12 -		6.5
10	4-07	55	9.0	5	0.4	95.5	6 -		12 -		6.0
13	1-07	7	1.2	2	0.2	83.3	- 5		12 -		6.5
14	28-06	24	4.0	0	0	100.0	3 -		- 11		8.5
17	22-06	47	7.8	1	0.1	98.7	3 -		- 9		6.5
18	4-07	130	26.0	72	5.5	78.8	6 -		- 9		3.5
21	1-07	30	5.0	0	0	100.0	- 6		- 11		5.0
22	1-07	185	23.1	24	1.8	92.2	6 -		10 -		4.0
Total & Average		549	10.0	105	1.0	90					

Pre-spray larval population sampling in the five blocks of this sector revealed no loopers in Block 1, a few in Block 5, and a relatively high population level in one plot of Blocks 2 and 3. In three plots in the centre of Block 4. 16.6 larvae per tree were recorded. Because loopers were present only in the centre of Blocks 2, 3 and 4, we modified the number and arrangement of these blocks (Figures 3 and 5). On July 3, 1972 there were 13.6 larvae per tree in the new block, No. 2 (Table 1).

Sector 2

As a result of intensive lumbering operations from 1946 to 1960, coniferous stands in Blocks 6, 9, 10, 13 and 14 were mainly composed of 25 to 50 year-old white spruce or younger (15 to 20 years old) in Blocks 17, 18, 21 and 22). Mature balsam fir stands were found only in the southern parts of Blocks 14, 17, 18, 21 and 22.

Except for the high larval population in blocks 18 and 22, all other blocks were below the critical level of ten larvae per tree; there were only a few or no larvae in one sampling plot out of three. Larval populations were below the critical level in four out of six sample plots in Blocks 10 and 14, and were very low in Block 13. The average larval population for all blocks of Sector 2 was ten larvae per sample plot (Table 2).

Table 1. 1972 pre- and post-spray hemlock looper larval populations in Sector 1 blocks and fenitrothion spraying dates.

Block No.	Pre-spray			Post-spray			Spraying			
	Date of last sample	No. of larvae	Average larv. pop. per tree	No. of larvae	Average larv. pop. per tree	Total mortality rate(%)	Hour 1st am	pm	Hour 2nd am	pm	Interval (days)
1	30-06	0	-	-	-	-	-	-	-	-	-
2	30-06	28	9.3	-	-	-	-	-	-	-	-
3	30-06	37	12.3	-	-	-	-	-	-	-	-
4	3-07	98	16.6	-	-	-	-	-	-	-	-
5	3-07	0	-	-	-	-	-	-	-	-	-
2 (2-3-4)	3.07	163	13.6	300 +	300 +	-	6	-	12	-	6.0

Pre-spray sampling indicated that the outbreak in this area had not spread since 1971. No looper was found in Blocks 39, 40 and 42, and only a few specimens were gathered in Block 38 (Table 4). Forest stands in Blocks 38, 39 and 40 had been partially felled. On the basis of these findings, only the northern halves of Blocks 41 and 42 were considered for spraying. The new Block 41 had an average of 97.7 larvae per tree.

Sector 5

Forest stands in this last sector were primarily composed of overmature balsam fir. In 1971 light defoliation was observed throughout this sector, except in Block 29 where there was no defoliation and stands in the eastern region suffered severe damage. Sampling beyond the area under observation added a new area (Block 36A) north of Grand Lac Salé to the spray program (Figure 5).

Table 5. 1972 pre- and post-spray larval populations in Sector 5 blocks and fenitrothion spraying dates.

Block No.	Pre-spray			Post-spray			Spraying				
							Hour				
	Date of last sample	No. of larvae	Average larv. pop. per tree	No. of larvae	Average larv. pop. per tree	Total mortality rate (%)	1st am	1st pm	2nd am	2nd pm	Interval (days)
29	30-06	39	6.5	22	1.8	72.3	5	-	-	9	4.5
30	21-06	207	34.5	454+	200+	-	6	-	12	-	6.0
31	22-06	234	39.0	21	2.6	93.3	5	-	-	9	4.5
32	21-06	68	11.3	36	4.0	64.6	6	-	10	-	4.0
33	30-06	127	21.0	34	3.4	83.8	6	-	10	-	4.0
34	30-06	639	106.5	181	9.0	91.5	6	-	10	-	4.0
35	30-06	529	66.0	646	40.0	39.4	5	-	9	-	4.0
36	30-06	763	85.0	326	40.0	53.0	5	-	9	-	4.0
36A	3-07	200+	200+	-	-	-	6	-	10	-	4.0
37	30-06	268	44.6	264	22.0	50.7	5	-	9	-	4.0
Total & Average		2667	50.3	1530	15.3	69.6					

Table 3. 1972 pre- and post-spray larval populations in Sector 3 blocks and fenitrothion spraying dates.

Block No.	Pre-spray			Post-spray			Spraying		
	Date of last sample	No. of larvae	Average larv. pop. per tree	No. of larvae	Average larv. pop. per tree	Total mortality rate (%)	Hour 1st am pm	Hour 2nd am pm	Interval (days)
7	1-07	29	4.8	13	1.0	79.2	12 -	- 5	6.5
8	1-07	46	7.6	16	1.3	82.8	6 -	12 -	6.0
11	1-07	62	10.3	3	.25	97.6	5 -	- 11	6.5
12	27-06	45	7.5	17	1.4	81.3	- 5	12 -	6.5
15	3-07	690	115.0	61	3.4	97.0	5 -	8 -	3.5
16	27-06	47	7.8	17	1.4	82.0	- 5	- 8	3.0
19	22-06	206	34.3	30	2.5	82.7	5 -	9 -	4.0
20	30-06	33	5.5	1	0.1	98.2	- 6	9 -	2.5
23	29-06	61	7.5	2	.25	96.7	6 -	12 -	6.0
24	29-06	30	5.0	4	.33	93.4	6 -	- 11	5.5
25	30-06	3	0.5	-	-	-	- -	- -	-
26	29-06	42	7.0	0	0	100.0	6 -	- 11	5.5
27	30-06	0	-	-	-	-	- -	- -	-
28	30-06	0	-	-	-	-	- -	- -	-
Total & Average		1291	19.0	164	1.3	93.2			

Table 4. 1972 pre- and post-spray larval populations in Sector 4 blocks and fenitrothion spraying dates.

Block No.	Pre-spray			Post-spray			Spraying		
	Date of last sample	No. of larvae	Average larv. pop. per tree	No. of larvae	Average larv. pop. per tree	Total mortality rate (%)	Hour 1st am pm	Hour 2nd am pm	Interval (days)
38	30-06	8	1.3	-	-	-	- -	- -	-
39	30-06	0	-	-	-	-	- -	- -	-
40	30-06	0	-	-	-	-	- -	- -	-
41	30-06	391	97.7	144	12.0	87.8	5 -	- 9	4.5
42	30-06	0	0	-	-	-	- -	- -	-
Total & Average		391	97.7	144	12.0	87.8			

defoliation was visible on trees near areas where all trees had been killed. These findings indicated that insect populations may have collapsed suddenly, probably in 1970.

Growth rings were studied on four trees which had survived the looper outbreak in Block 47 near Lake Victor. Growth decreased markedly in 1969, indicating severe defoliation began in 1968. Lack of time prevented us from verifying these findings at other sites in the area. However, the great extent of tree deterioration, the absence of twigs on main branches, broken branches, and bark which could easily be detached from tree trunks, suggested that the hemlock looper outbreak on the North Shore was prior to the Anticosti Island infestation. This outbreak probably ended in 1971. Hemlock looper moths were still observed in infested areas near Havre-Saint-Pierre and Natashquan when surveys were conducted in September 1971. Based on these findings, spray operations planned for this area were cancelled.

Results of spraying on Anticosti Island

The maximum time to carry out spraying is twenty-five days (Otvos *et al.* 1971). Spraying should begin three days after the first "significant number" of ten larvae per tree are observed in a sample plot; spray operations are terminated when 30% of larvae have reached L_3. For maximum foliage protection spraying should be completed within the first fifteen days. Because egg hatching lasts three weeks, and to ensure maximum foliage protection, it was recommended that two applications of insecticide be used with a 6 to 8 day interval between them. Fifteen TBM Avenger aircraft, flying in groups of three, were to apply fenitrothion between July 3 and 12.

The first "significant number" of ten larvae per tree in a sample plot were observed on June 20 in a stand near Baleine Creek, as well as the following day in most blocks located in the Sainte-Marie and Jupiter River watersheds. Spraying was to have begun on June 28 but started on July 3 because of unfavourable weather which delayed the arrival of aircraft at Port-Menier. The first spraying of 171 800 ha was completed on July 6.

The extremely high larval population in Sectors 3 and 5 and the advanced stage of larval development because of favorable weather conditions for

Table 5 shows results of pre-spray sampling. Eight of nine blocks had a larval population above the critical level of 50.3 per tree. The homogeneous distribution of larval populations distinguished this sector from other sectors.

The original program was to spray 218 212 ha, divided into 42 units of 5 100 ha each (Figure 3). As a result of pre-spray larval population sampling 51 000 ha (ten blocks) were excluded because no larvae were found or populations were below the critical level (Figure 5). The following changes were made:

Sector	Changes to spraying plan (blocks)		
	Rejected	Modified	Added
1	1-5	2-3-4*	-
2	-	-	-
3	25-27-38	-	-
4	38-39-40	41-42**	-
5	-	-	36A

* New Block No. 2

** New Block No. 41

Pre-spray larval population survey - North Shore

Pre-spray hemlock looper larval population surveys were carried out by helicopter on July 4 and 5, 1972, in twelve of the fourteen areas to be sprayed on the North Shore. Blocks 43 and 51 could not be sampled as there were no suitable landing sites. From four to eight conifers were sampled at two or three accessible sites in each block. Larvae were not found in any of the areas, except for one of three sample plots in Block 56, located near Mont Sainte-Genevieve, where six larvae were gathered from eight trees.

Young balsam fir trees located on the fringes of dead balsam fir stands near Havre-Saint-Pierre, Natashquan and Lake Kégashka showed no defoliation. Furthermore, 1970 and 1971 foliage on old trees surviving the looper outbreak which probably started in 1968 or 69, remained intact; however, older foliage had suffered varying degrees of damage. At Lake Victor, no

mortality was obtained for all blocks in Sector 5. In this latter sector post-spray sampling seemed to indicate that spraying had failed in Block 30 and was partially successful in four other blocks (Nos. 32, 35, 36 and 37). Larval population increased in Block 2 of Sector 1; this can be attributed to local weather conditions which delayed looper development. The spray was 79.4% effective throughout the area, excluding Block 2 of Sector 1 (Table 6).

Defoliation and tree mortality survey

An aerial survey of defoliation and tree mortality in stands infested by the hemlock looper was carried out by helicopter on Anticosti Island from July 18 to July 26 in both sprayed and unsprayed areas. The survey was to evaluate the effectiveness of the program and to locate residual post-spray insect populations.

From 171 160 ha receiving two applications of fenitrothion, 154 850 ha (90.2%) showed no sign of defoliation and 16 900 ha (9.8%) had been damaged to varying degrees: light defoliation on 125 ha, moderate defoliation on 5 780 ha, and severe defoliation on 11 000 ha (Figure 5). More than 90% of all defoliation occurred in Sector 5. The remaining defoliated stands were observed in Blocks 2, 15 and 41. The defoliation observed on the fringes of Block 2 (near Port-Menier) on July 24, 1972, affected two stands for a total of 121 ha. Two weeks later, an aerial survey revealed that these two infested areas had considerably increased to cover 1 340 ha; 716 ha were located within the sprayed block (Figure 6). This late manifestation of larval populations and subsequent damage by the hemlock looper was attributed to a delay in hatching, probably because of less favourable local weather conditions.

Damage of widely varying intensity was recorded in irregular patches in unsprayed stands covering almost 54 640 ha between the Brick and Chaloupe Rivers, and in the Vauréal River watershed. These variations were attributed to high tree mortality in 1971 and the heterogeneous composition of the forest in sectors surviving severe defoliation. (Figure 6).

The extent of tree mortality on Anticosti Island was assessed more precisely by the 1972 aerial survey. Trees had been destroyed on 138 200 ha; tree mortality exceeded 50% on 64 250 ha. Slightly more than half (45 900 ha) the area east of Brick River had 50% higher mortality (mainly balsam firs) at the end of July (Figure 7). Losses were estimated at 7 139 000 m^3 (Jobin 1980) of wood.

hemlock looper, made it necessary to shorten the interval between applications to four days. The second spray operation, of 171 725 ha, began July 8 and ended July 12.

Spray effectiveness was evaluated using three methods: larval mortality survey, extent and degree of defoliation, and abundance and distribution of looper moths.

Larval population survey

Post-spray larval population sampling took place ten to twelve days after the second spray operation in each of the three sample plots in the thirty-two blocks sprayed. The sampling technique was the same as that used for pre-spray sampling. The larval population of two trees in each sample plot was estimated, and two additional trees were also examined. In each block six trees were sampled before spraying and twelve afterwards.

The sampling results are summarized in Table 6. The larval mortality or effectiveness of spraying in Sectors 2, 3 and 4 was 90%; 69.6% larval

Table 6. Pre- and post-spray larval populations in the 5 sectors sprayed with fenitrothion and mean larval mortality for each sector, Anticosti Island, 1972.

Sector	Pre-spray			Post-spray			Total mortality (%)
	No. of trees sampled	No. of larvae	Average larv. pop. per tree	No. of trees sampled	No. of larvae	Average larv. pop. per tree	
1	12	163	13.6	6	900	150	Population
2	55	549	10.0	110	105	1.0	90.0
3	68	1291	19.0	126	164	1.3	93.2
4	4	391	97.7	12	144	12.0	87.8
5	53	2667	50.3	100	1530	15.3	69.6**
Total	180	4898	27.2	348	1943	5.6	79.4

* Data from sector 1 are not included in the estimate of total mortality.
** Data from Blocks 30 and 36A are not included.

Moth population survey

Sampling of moth populations was carried out to more precisely assess the effectiveness of spraying, to locate residual populations, and to estimate their relative importance. To determine when the moth survey should begin and the peak of adult emergence 1 145 pupae were collected August 28 and 595 September 6.

Tree trunks were beaten with a club and the number of moths which flew away were counted. Nineteen blocks, accessible by road, were sampled; in each block, twenty trees were examined at six different sites. Sampling began September 7 and ended one week later. Ten Pherocon-1C traps, each containing two one-day-old virgin female moths were also set out in ten of the nineteen blocks sampled to detect male hemlock loopers.

The first moths were recorded on August 28 near Block 2 of Sector 1, and on August 29 in Block 34 of Sector 5. Adult emergence peaked between September 6 and September 10 and was completed by the end of the third week of September. The results are recorded in Table 7 and compared with the results of the 1971 adult looper sampling, as well as with those from two unsprayed areas in the Vauréal River watershed. Looper populations decreased quite noticeably in all sprayed blocks except Blocks 35 and 41, and in Block 2, which was not sprayed because eggs hatched late.

Results of defoliation survey - North Shore

Aerial surveys were carried out July 12 and 28 to verify results of previous larval populations surveys in areas damaged by hemlock looper on the North Shore. Hemlock looper populations had collapsed in this area and no defoliation was observed.

AERIAL SPRAYING, 1973

An aerial survey of balsam fir stands defoliated by hemlock looper on Anticosti Island in 1972 indicated damage on 16 900 ha located almost entirely within the sprayed area (Figure 6). A second spray program was planned during the winter of 1973 to end the looper outbreak on Anticosti Island. Using a CL-215 aircraft based in Bonaventure, Gaspé, two applications of fenitrothion were to be sprayed at a seven-day interval and a rate of 1 461 L/ha each.

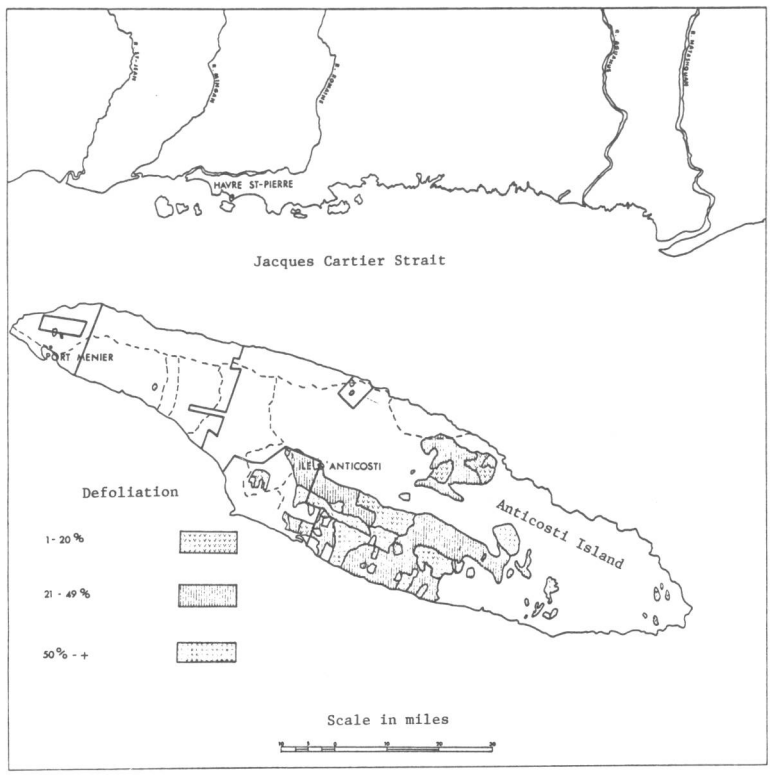

Figure 6. Defoliation caused by hemlock looper in 1972 on Anticosti Island in sprayed and unsprayed sectors.

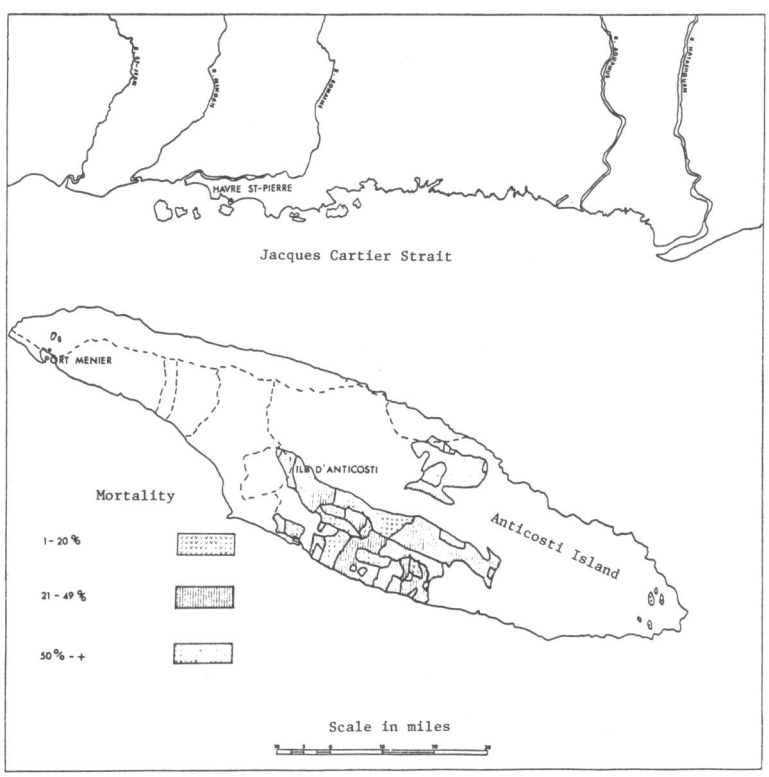

Figure 7. Tree mortality caused by hemlock looper on Anticosti Island in 1971 and 1972.

Two teams of two persons each sampled the infested area. In addition another team in a helicopter checked the forest condition and insect population levels beyond areas sprayed in the original program. No egg population survey was carried out in 1973.

Larval population sampling was done fifteen days after the second spraying. To clearly establish the size of post-spray residual populations, ten burlap traps for collecting pupae and ten Pherocon-1C traps for collecting moths were set on ten balsam fir trees in each of the five sampling plots in the area sprayed and in a control plot. The burlap traps were set on July 24, 1973, and their contents examined on August 8. Three virgin female looper moths were placed in each of the Pherocon-1C traps on August 22 and males were counted on one occasion, in early September.

Pre-spray larval population sampling was done on four occasions between June 10 and July 2 in the area infested at the end of 1972 and included in the original 1973 aerial spray program. This sampling indicated an almost complete collapse of insect population on 12 720 ha. Larval population per tree was 1.6 and a maximum of 3 larvae were observed on any one tree.

Populations, well below the critical level, were recorded two days before spraying in stands near Port-Menier. The results of the sampling, expressed as the average number of larvae per tree, showed that larval populations varied from 24 to 168 in the seven sampling plots surveyed (Table 8). Larvae per tree were estimated at 85.6 two days before the first spraying. On the same day, 233 larvae per tree were recorded in the control plot. The 4 180 ha defoliated in 1972 (Figure 8) and sprayed in 1973 (Figure 9), were composed of stands originating from lumbering operations of 1910 to 1917.

Results of spraying

The first spraying took place June 30, 1973, but over 2 540 ha of the infested area, spray operations were halted because of a change in weather. A technical error resulted in the insecticide containing both fenitrothion and phosphamidon; only fenitrothion was used during the second spraying of the area on July 7. The remainder of the infested area (1 640 ha) received only one application of fenitrothion on July 9, because 77.5% of larvae had reached L_3 by July 8. Spraying normally ends when 30% of larvae have reached L_3.

Table 7. Comparison of hemlock looper adult populations on Anticosti Island, 1971 and 1972.

Sector	Block No.	Average number of adults		
		Per tree		Per trap
		1971*	1972**	1972
	1	1-20	0.3	-
1	2 (2+3+4)	1-20	20++	269
	5	0	0	-
	6	1-20	0	-
	9	1-20	0	-
	10	20+	1	4
	13	1-20	0	-
	14	1-20	0.6	18
2	17	1-20	0	-
	18	1-20	0	-
	21	1-20	0	-
	22	0	0	11
	12	20+	1	7
3	16	20+	0.2	35
	24	0	0	-
	26	0	0	1
4	41	20+	20+	59
	34	20+	0.1	31
5	35	20+	20+	54
Control	Live tree	20+	20++	256
	Dead tree	20+	3	6

* Number observed on 1 tree

** Average calculated for 25 trees

Fifty hectares, located within the infested area, would not be sprayed in order to test an insect growth regulator as a means to control the hemlock looper (Retnakaran *et al.* 1973).

Description and results of pre-spray sampling

The techniques used in 1972 to study the development of hemlock looper larvae, to estimate pre- and post-spray insect populations, and to clearly define the boundaries of the infested area were also used for the 1973 survey. However, the number of sample plots per 5 100 ha block was increased to 4, so that more information could be gathered on the biology of the hemlock looper and on the effectiveness of spraying.

Significant larval mortality was observed in sprayed areas and in the control plot (Table 8). In the latter larval mortality was 94.8%. In stands sprayed once, it was 96.6%, and 97.5% in stands sprayed twice. An insect pathogen of the genus *Entomophthora* caused mortality in the control plot. This fungus was also observed in the sprayed area before insecticide was applied. These findings indicate that fenitrothion may not have been the sole factor responsible for the collapse of looper populations.

Pupal and adult looper population sampling results (Table 8), revealed a greater decrease in looper populations in sprayed than in control areas. We cannot explain why residual pupal and adult population levels were higher in areas receiving two applications of fenitrothion than in those receiving only one; evidently the application of this insecticide was not the only factor leading to a decrease in looper population levels. Therefore effectiveness of the 1973 spray program cannot be evaluated.

Table 8. Results of 1973 pre- and post-spray hemlock looper larval, pupal and adult population surveys in sprayed and control areas.

No. of insecticide applications	Plot	Pre-spray Larvae/tree		Post-spray population and mortality rate (%)				
				Larvae		Pupae		Adults
		Tot.	Avg.	Avg./Tree	Mortality	Avg./Trap	Mortality	Avg./Trape
1	Lake Claude	330	41	4.0	90.3	5.5	0	6.1
	Duck Lake	569	71	1.0	98.6	2.2	0	4.3
	3 Mile River	189	24	1.3	94.6	-	-	-
	Airport	1248	156	1.0	99.4	-	-	-
2	Lake Plantain	513	64	9.0	85.9	14.3	17.4	22.9
	Lake Superior	602	75	0.5	99.3	12.4	14.5	15.2
	Lake Gamache	1346	168	1.0	99.4	7.1	8.4	16.4
Control		1863	233	12.0	94.8	60.3	0.2	32.2

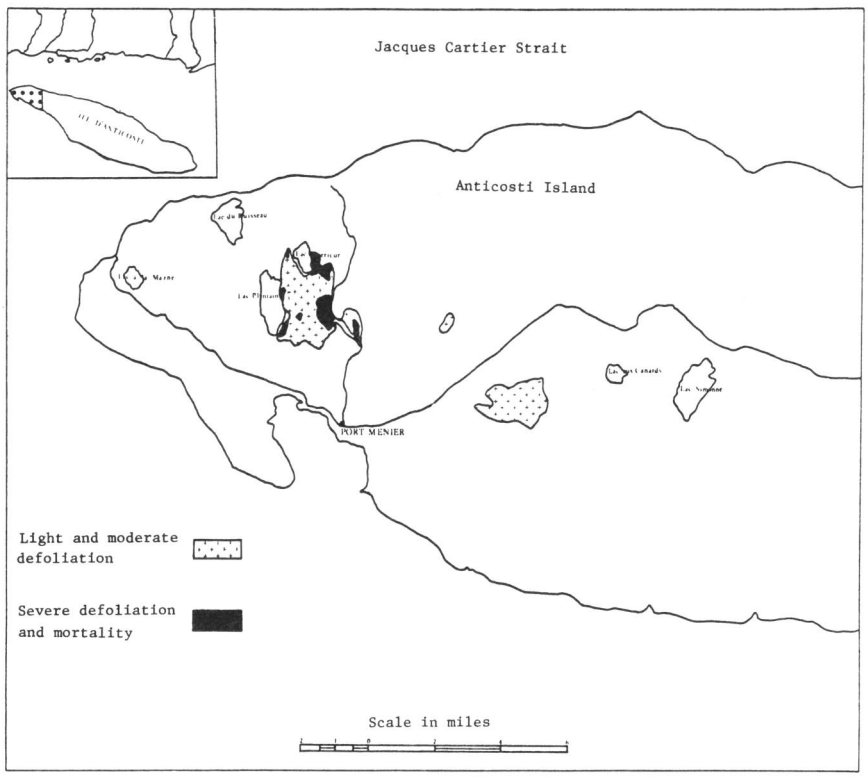

Figure 8. Defoliation caused by hemlock looper in 1972 in Sector 1, near Port-Menier.

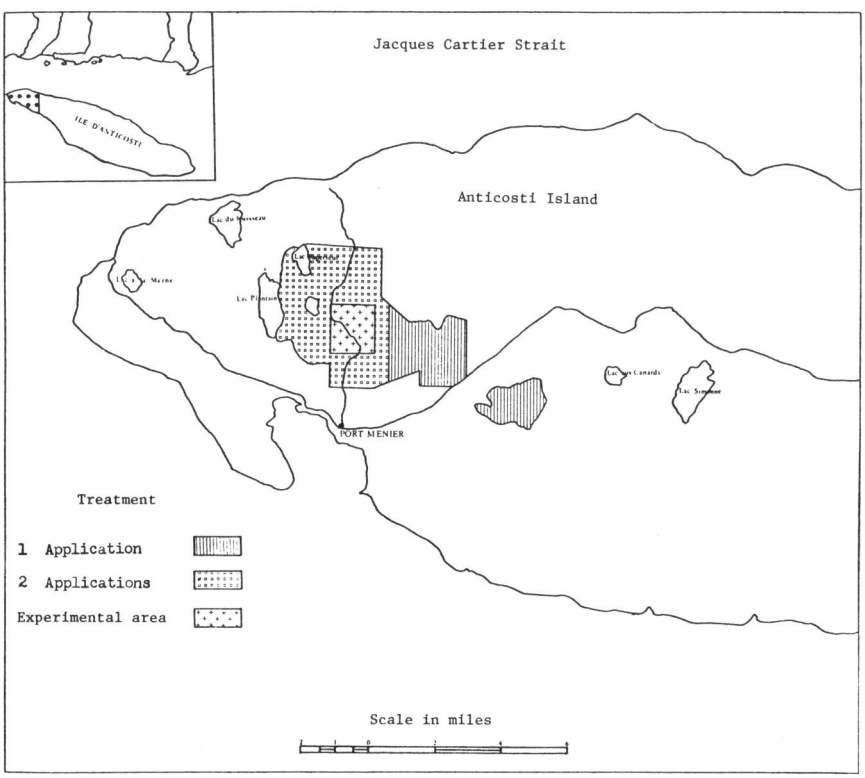

Figure 9. Areas on Anticosti Island sprayed with fenitrothion in 1973.

Defoliation survey

On July 26, 1973, defoliated stands were surveyed using a Beaver aircraft. Light to moderate defoliation was observed on 1 023 ha out of a total 4 180 ha sprayed; of this defoliated area, 541 ha were in stands sprayed once and 483 ha in stands sprayed twice with fenitrothion. Tree mortality was observed on 129 ha (Figure 10). There was no defoliation anywhere on Anticosti Island beyond the sprayed area.

In summary, one-fourth of the area sprayed in 1973 was defoliated by the hemlock looper. However, we cannot conclude that fenitrothion was the sole factor responsible for protecting foliage in stands not defoliated. A fungus of the genus *Entomophthora* also contributed to the collapse of looper populations on Anticosti Island in 1973.

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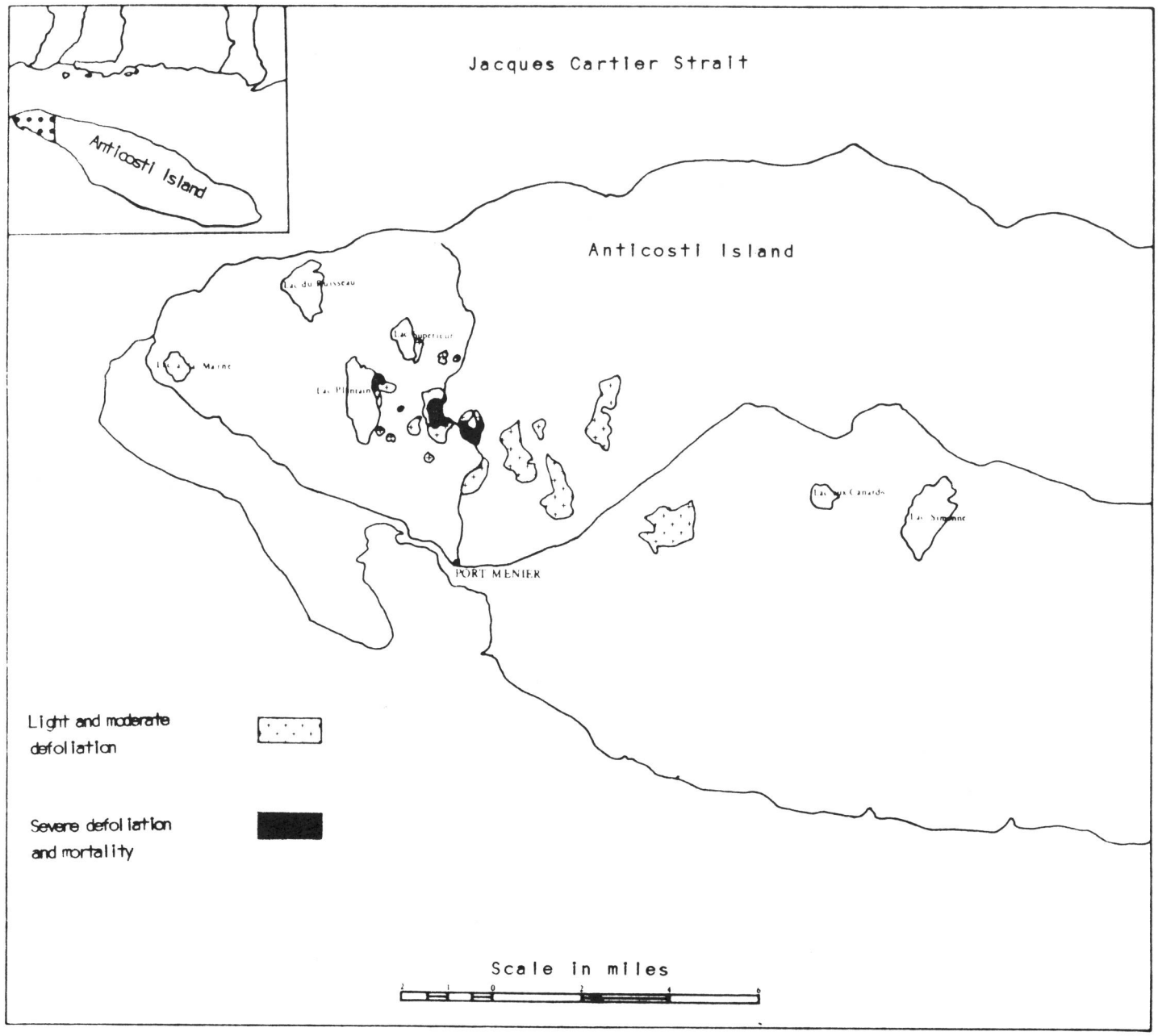

Figure 10. Areas infested by hemlock looper in 1973.

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