THE HEMLOCK LOOPER IN NEWFOUNDLAND: THE OUTBREAK, 1966 TO 1971; AND AERIAL SPRAYING, 1968 AND 1969

by

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TABLE OF CONTENTS

	Page
Introduction	1
Life History and Habits of the Looper	2
Eggs	3
Larvae	4
Pupae	6
Adults	6
Characteristics of Outbreaks	7
Events Leading to the Spray Program	9
The Spraying Operation - 1968	13
Estimate of Areas Requiring Protection	14
Defining Areas Requiring Protection	15
Larval survey	15
Defoliation survey	18
Aerial Spraying	18
Effectiveness of Spraying	21
Larval survey	21
Defoliation survey	23
Moth survey	24
Problems Encountered	25
The Spraying Operation - 1969	30
The Task Force	30
Estimate of Areas Requiring Protection	31
Defining Areas Requiring Protection	32

	Page
Larval survey	33
Defoliation survey	35
Aerial Spraying	36
Effectiveness of Spraying	38
Larval spraying	39
Defoliation survey	40
Moth survey	41
Problems Encountered	42
Effects of Spraying on Fish and Wildlife	43
Recommendations	45
Cost of Spraying	47
Appraisal of Damage	48
Factors Responsible for the Decline of the Outbreak.	51
Conclusions	53
Literature Cited	57
Appendix I	60
Appendix II	62

LIST OF FIGURES

Figure 1 - Diagramatic life history of the eastern hemlock looper in Newfoundland ----------

Figures 2-5 - Life stages of the eastern hemlock looper ------

Figure 6 - Major geographic divisions, place names and airfields ----------

Figure 7 - Areas defoliated by the hemlock looper in 1966 and 1967 ----------

Figure 8 - Areas delineated for protection in 1968 ----------

Figure 9 - Distribution and relative density of larval sample points in 1968 ----------

Figure 10 - Areas sprayed in 1968 ----------

Figure 11 - Areas defoliated by the hemlock looper in 1968 ---

Figure 12 - Areas delineated for protection in 1969 ----------

Figure 13 - Distribution and relative density of larval sample points in 1969 ----------

Figure 14 - Areas sprayed in 1969 ----------

Figure 15 - Areas defoliated by the hemlock looper in 1969 ---

Figure 16 - Areas defoliated by the hemlock looper in 1970 ---

Figure 17 - Areas defoliated by the hemlock looper in 1971 ---

only on 59,800 acres in 1971. The outbreak will be in its seventh year in 1972 and indications are that it will continue to decline and defoliation will be neglegible.

This report describes the life history and habits of the insect and documents the history of the current outbreak. It summarizes the planning and organization of the spray program, discusses the problems encountered, and evaluates its success.

Only one of the authors, L.J. Clarke was actively involved in the chemical control operations. Therefore, most of the information was taken from the files or was provided by W.J. Carroll, Director, and G.L. Warren, who was Head of the Forest Insect and Disease Survey at the time of the operations.

Hopefully, the report will provide a guide for planning any similar program that might be contemplated in the future. There is no doubt that hemlock looper outbreaks will occur again in Newfoundland and indications are that another might begin by 1976. As the demand for wood increases on the Island, so also will the need for protection from insect losses intensify. It is, therefore, not inconceivable that periodic spraying operations will become an essential part of forest management in the Province.

LIFE HISTORY AND HABITS OF THE LOOPER

A detailed knowledge of the life history of a forest insect is prerequisite to planning and conducting any successful control operation. The selection of appropriate larval sampling methods and the timing of spray application is determined by the seasonal history and habits of the insect. The rate of larval development, and the phenological variability between localities, should be well understood so that adjustments can be made in spray dosages and in the timing of intervals between treatments.

Details of the biology of the eastern hemlock looper have been documented by various authors. Studies in Ontario and Quebec have been reported by de Gryse and Schedl (1934) and by Watson (1934), and Carroll (1956) described the life history of the looper in Newfoundland. Additional information has been collected during the present outbreak. The generalized life cycle is illustrated in Figure 1.

<u>Eggs</u>

Eggs (Fig. 2) are broadly oval and less than 1 mm in width. At first they are pale green but turn copper-brown in about 15 days if fertilized, remain green if sterile, and turn black if parasitized. They are laid from late August to October with the peak period occurring during late August and early September. They are deposited singly, or in groups of two or three, on a variety of substrates. Weather during the oviposition period influences the selection of oviposition sites. During windy, cool, and moist periods, mosses, stumps and undergrowth are favored, but during calm, warm periods, the upper bole and crown of the host and other tree species are utilized.

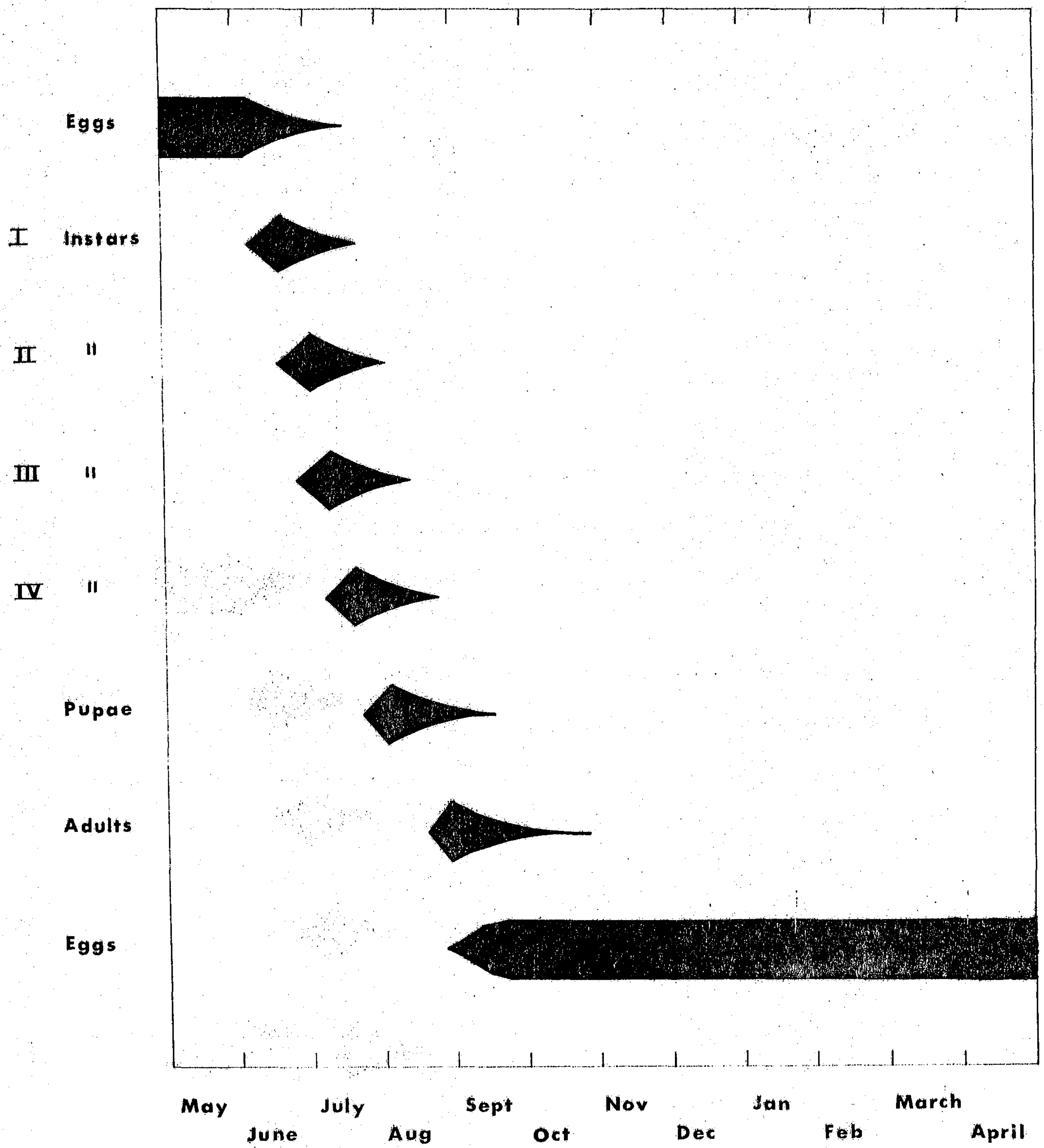


Fig. 1, Diagramatic life history of the eastern hemlock looper in Newfoundland.

develop through the 2nd, and later instars, reddening and subsequent browning becomes more apparent. During the 3rd and 4th instars old foliage is attacked almost exclusively. These older larvae are wasteful feeders, usually consuming only a part of the base or side of a needle before moving on to feed on another needle. Feeding is most severe during July. However, severity of damage may not become obvious until mid-July because the partially eaten needles remain on the trees and require several days to turn red. Fully fed larvae, and those disturbed by rain, wind, or parasites, drop from the foliage to the ground on silken threads and may later be observed crawling up the stems of trees in search of new feeding sites.

Larvae are present in the field from early spring until late summer. The developmental period lasts about 50 days averaging 14.1 days for the 1st; 9.5 days for the 2nd; 9.7 days for the 3rd; and 15.6 for the 4th larval instar. There is considerable overlap among the four larval instars; for example, during the week beginning July 12, 1970, all four instars were present. There is also a wide variation in seasonal development between years. As examples there were 11 days between the time when 30% of the larvae were in the 2nd instar and the time when 30% of the larvae reached the 3rd instar in 1970; the same development required 15 days in 1950, 14 in 1968, and 16 in 1969, all in the same general location of the Island.

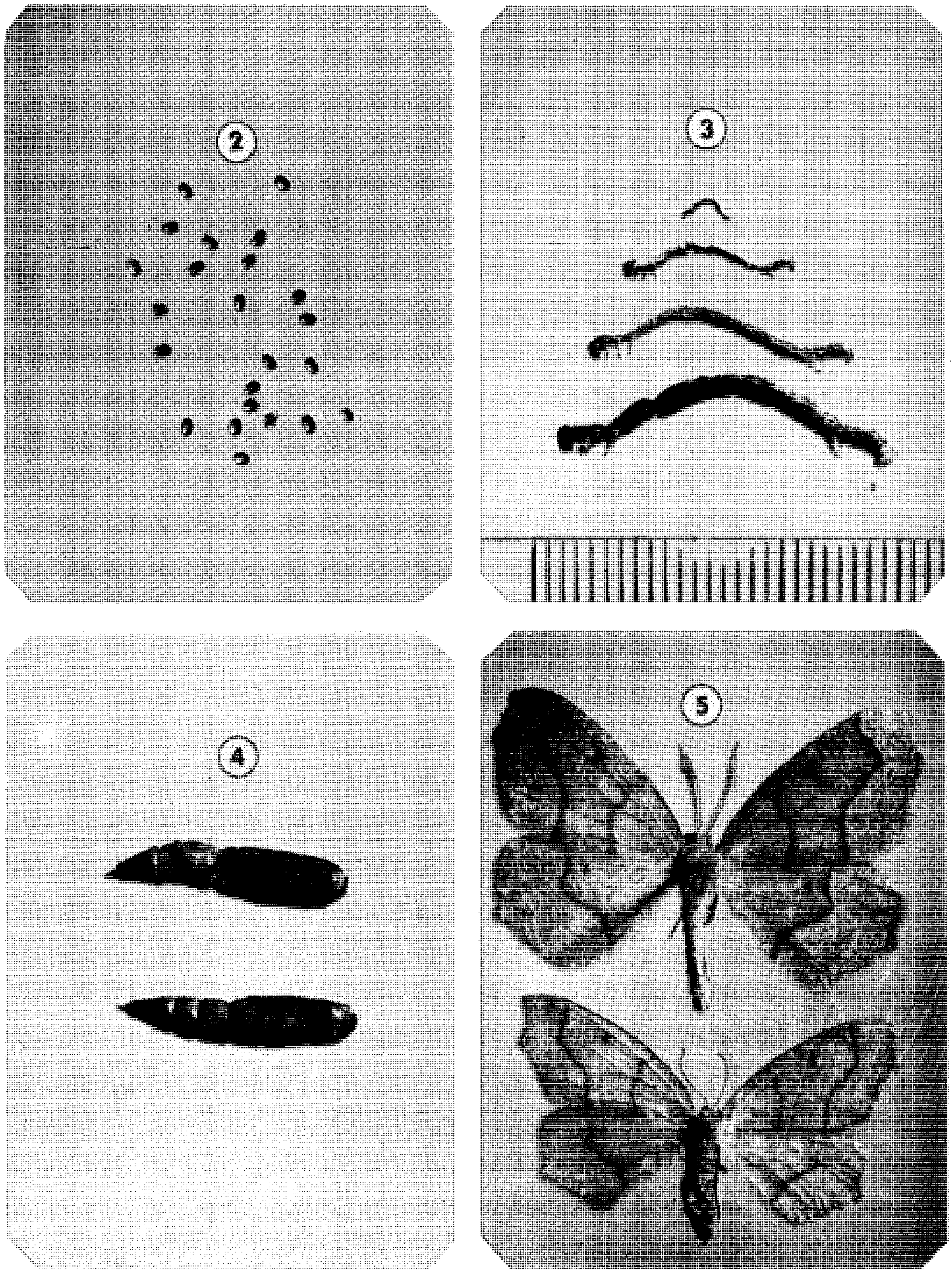
Pupae

Pupae (Fig. 4) when newly formed, are light green but change later to yellowish-green through light brown to a dark brown color. Pupal length varies from 11 to 16 mm (7/16-5/8 inches). Pupation begins in late July and continues through August. The pupal stage lasts about 3 weeks. Preferred pupation sites are dry, protected places including bark crevices, loose bark, and among lichens and mosses around and on tree trunks.

Adults

Adult moths (Fig. 5) vary in color from creamy-tan to greyish-brown. They have a wing span of about 32 mm ($1\frac{1}{4}$ inches). The forewings have two irregular purple-brown transverse lines, with a similarly colored dot between the lines. The hind wings have only one transverse purple-brown line. Adult emergence begins in late August and moths can be found in the field until late fall with a peak abundance in early September. They are generally inactive during the day and begin flying in late afternoon. They are poor fliers, and although wind may carry them for considerable distances over open country, there is no evidence that moth flights contribute appreciably to the spread of infestations.

Preliminary investigations showed that adult females, collected as pupae, from a newly infested and moderately defoliated stand laid the highest number of eggs, average 76



Figs. 2 - 5. Life stages of the eastern hemlock looper: 2, eggs (4X); 3, first-, second-, third-, and fourth instar larvae, (each horizontal line equals 1mm); 4, female pupa, dorsal and ventral views (2X); 5, (upper) male and (lower) female adult(2X).

per female. Conversely, the lowest number, average 24, were laid by females from an older infestation where the stand was more severely defoliated. Data also showed that the proportion of fertile eggs was always high, about 75%, and was not influenced by the age of the outbreak.

CHARACTERISTICS OF OUTBREAKS

The history of the hemlock looper in Newfoundland indicates that outbreaks are cyclic, usually occurring during periods of warm, dry weather. The increase in larval numbers to outbreak proportions is rapid. As an example, prior to the current outbreak numbers of looper larvae were .02 per tree sample in 1964 (n = 359), 0.06 in 1965 (n = 741), and 0.11 in 1966 (n = 728). Outbreaks generally begin as small, scattered infestations which increase in size and distribution annually. Often these scattered infestations coalesce to form a large irregular outbreak area. Damage is most severe in mature and/or overmature stands of balsam fir although severe damage has been recorded in younger stands. For example, trees were killed in a 40 year old stand near Lake Ambrose in central Newfoundland. However, this stand contained some scattered overmature trees left from previous logging, and was within ½ mile of a mature (78 years old) stand that was severely attacked. Previous damage caused by other insects or diseases and weakening caused by adverse site conditions increases stand susceptibility.

Heavily infested stands are readily recognized by the reddish-brown color of the partially-eaten foliage and by the masses of silken threads. The former may remain on the trees for more than a year. Dead trees and dead tops give older outbreaks a characteristic grey appearance.

Individual infestations usually collapse in about 2 years. Moist weather cycles cause a general decline in larval numbers, primarily because conditions favor an increase in the incidence of entomogenous fungi. Present studies suggest that two Entomophthora spp. are involved in the collapse of outbreaks. Results of sampling indicate that these fungi were responsible for terminating outbreaks at Serpentine Lake and McIvers in 1969 and possibly a large outbreak near Bay d'Espoir in 1970, and at Birchy Lake and Lake Ambrose in 1971. Local infestations can also collapse because of larval starvation following severe defoliation. In Newfoundland, complete starvation and resultant larval mortality has not been observed. However, partial starvation with its subsequent effects, such as increased susceptibility to disease and reduction in the number of eggs produced, is common.

Several insect predators and parasites attack various stages of the looper but none appear to appreciably influence the pattern of an outbreak. Tachinids were the most important parasites during the current outbreak. Parasitization by these flies increased with the age of the infestation and high larval parasitism was recorded in localized situations. For example, parasitism was 34% at Serpentine Lake in 1969 and 43% at Frenchman's Cove in 1970. Both localities are in western Newfoundland. The average parasitism by tachinids on the Island was 13% in 1969 and 17% in 1970. Parasitism by hymenopterous wasps was low, about 1% in 1969 and 1970. This is contrary to results obtained during an outbreak in 1952, when parasitism by Hymenoptera was 30% and by Diptera less than 1%. Little is known of parasitism of hemlock looper eggs, but the hymenopterous parasite, Telenomus sp., killed 18% of eggs collected in the field and reared in the insectary. This high parasitism occurred in eggs collected from birch bark, but in eggs collected from moss, only one in 5000 was parasitized.

Twenty-one species of birds were found to prey on the hemlock looper. In 1969 more than 40% of the diet of these birds consisted of all stages of the looper, but only 20% in 1970. Individual birds at times fed exclusively on the looper; 3rd and 4th instar larvae, and pupae were found most commonly in the crops of these birds (Otvos and Taylor 1970).

EVENTS LEADING TO THE SPRAY PROGRAM

In 1966 light defoliation occurred in 300 acres of fir in the Crabbs River and Bottom Brook watersheds in western Newfoundland, indicating the beginning of a new hemlock looper outbreak. In

1967, this outbreak expanded over an area of approximately 120,000 acres of mature fir. Small localized areas of defoliation were also recorded in central Newfoundland (Fig. 7*). Surveys in the fall showed that looper moths were numerous in defoliated and adjacent undamaged stands indicating the probability of a further extension of the outbreak in 1968 (Warren, 1967). When advised of this situation, the two paper companies, Bowaters Newfoundland Limited and Price (Nfld.) Pulp and Paper Limited, indicated that they could salvage existing severely damaged stands on their limits, but that any major expansion of the outbreak could jeopardize the future of the pulp and paper industry in the Province. In fact, Bowaters stated that they would spray their own limits if other agencies did not wish to co-operate in a chemical control operation.

This strong attitude in favor of control action prompted the Newfoundland Forest Research Centre to arrange a meeting on September 7 of agencies** likely to be concerned should a spraying operation be undertaken. Two more meetings were held between September 1967 and January 1968. The first meeting, held at Bowaters at Corner Brook, was attended by representatives of Bowaters Newfoundland Limited (Bowaters), Price (Nfld.) Pulp and Paper Limited (Price), Newfoundland

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*Fig. 6 shows the major geographic divisions of the Island and the place names, including airfields, referred to in this report.

**Appendix I lists names and abbreviations where applicable.

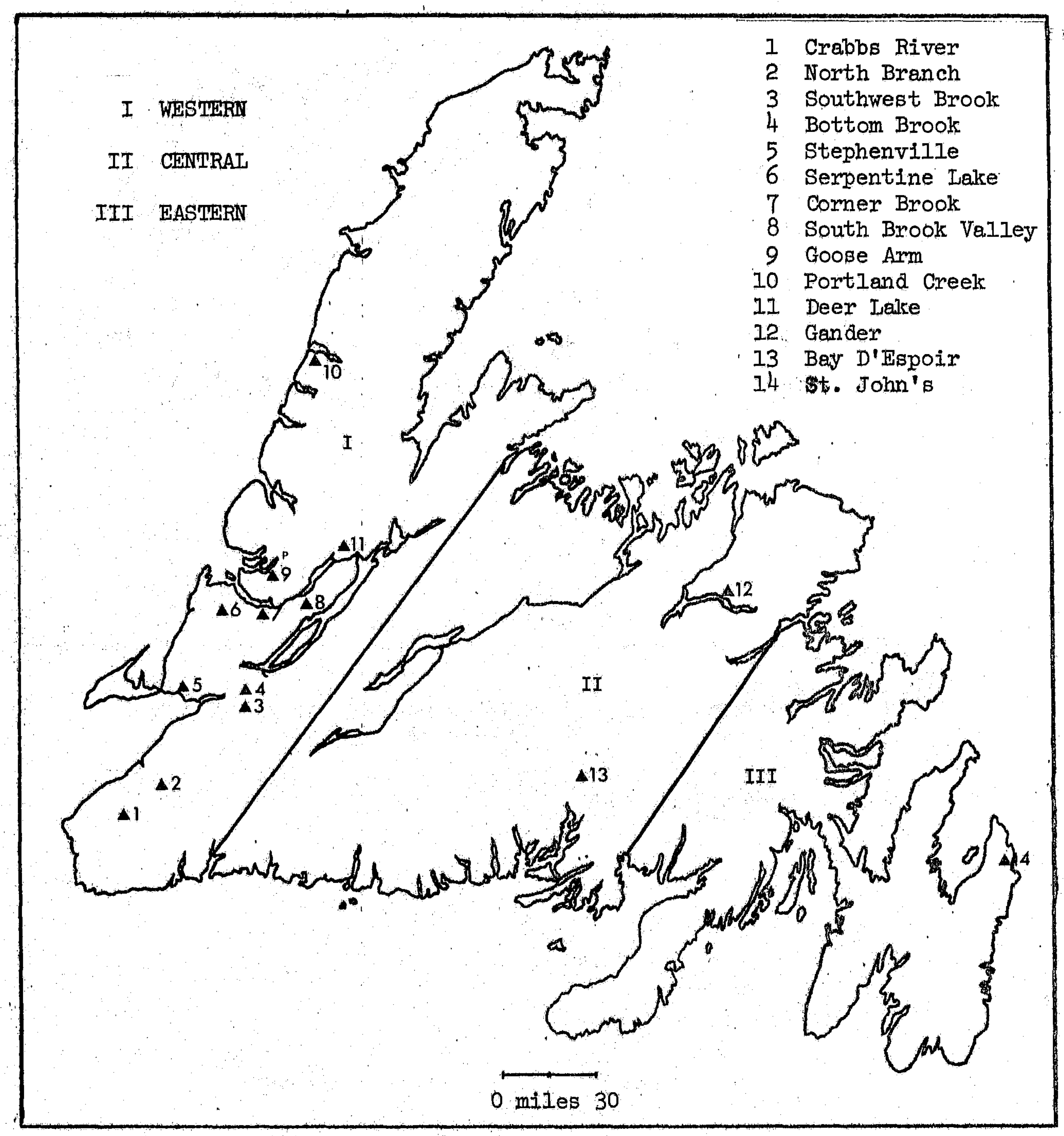

Fig. 6, Major geographic divisions, place names and airfields referred to in this report.

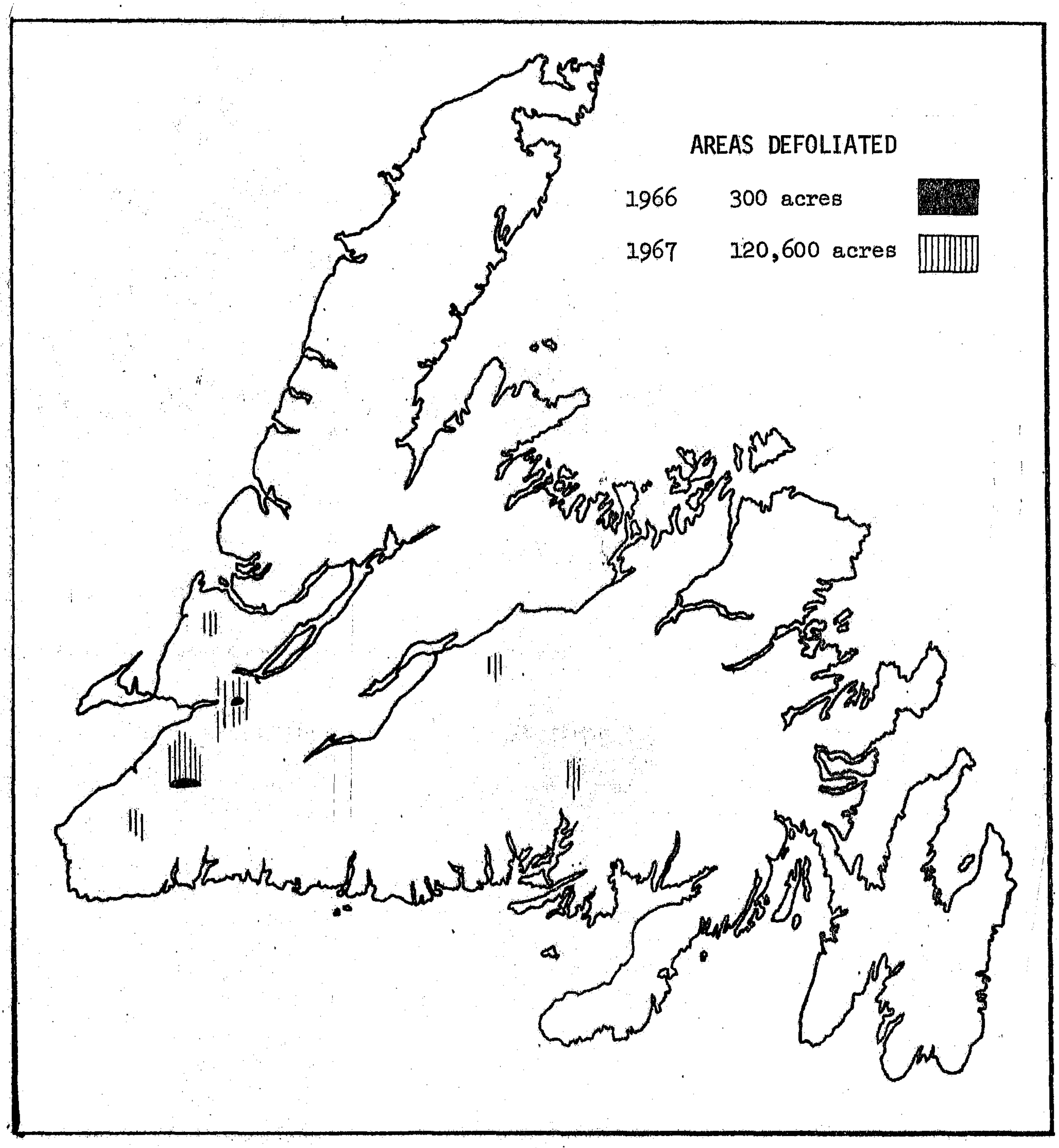

Fig. 7, Areas defoliated by the hemlock looper in 1966 and 1967.

Forest Service (NFS), Newfoundland Forest Research Centre (NFRC), the Chemical Control Research Institute (CCRI), Ottawa, and the Fisheries Service of Canada, Newfoundland Region. The second meeting, held October 3 at the NFRC office at St. John's, also included a representative of the Newfoundland Wildlife Service. The third meeting, held January 3, 1968, included all representatives from the two previous meetings and Dr. G.S. Cooper, Cyanamid of Canada Limited and Mr. B.W. Flieger, Forest Protection Limited (FPL) of New Brunswick.

At the first meeting, the NFRC reported on the status of the 1967 outbreak and presented its forecast for 1968. It was emphasized that the outbreak would probably be more severe than in 1967 and that if a spraying program was to be undertaken an early decision should be reached. It was stressed, that to be successful, the planning of such a complex operation should begin immediately. The meeting was advised that only a low level of accuracy in locating potential outbreaks could be provided from fall forecasts and that larval surveys would be required in the spring of 1968 to define the areas requiring protection. However, the meeting was advised that the results of a moth survey, the maps of areas infested in 1967, and available information on the location of vulnerable stands would provide the basis for broad planning of a spray operation.

Industry representatives recommended an aerial spraying operation to protect their limits. Representatives of NFS stated that any spray operation would require authorization of the Provincial Government. The CCRI representative suggested, that should a spraying program be undertaken, the organophosphate insecticides, fenitrothion and phosphamidon, would provide suitable alternatives to the highly controversial DDT.

At the second meeting additional information on the status of the looper outbreak was presented. New records of occurrence of moths had been obtained and it was suggested that the ideal fall weather conditions increased the probability of a more severe outbreak than had been originally forecast. It was unanimously agreed that the Provincial Government be requested to authorize a chemical control program for 1968. Fisheries and Wildlife officials stated they could not accept the use of DDT but felt that an organo-phosphate insecticide at a low dosage should have no deleterious effect on fish and game. The limit holders (Bowaters, Price and NFS) agreed to provide maps showing the location of susceptible stands and their priorities for protection. Using this information and survey data on looper conditions the NFRC agreed to prepare a composite map of the Island to show the extent of areas that would probably require spraying. The meeting also emphasized the importance of having FPL conduct the spraying operation as it was the only experienced forest spraying agency in eastern Canada.

At the third meeting the NFRC again reviewed the status of the looper outbreak and forecast that an area of more than 500,000 acres would be heavily infested. On the recommendation of the CCRI it was decided to use the insecticides fenitrothion and phosphamidon. The latter was recommended for use over major waterways because of its lower toxicity to aquatic life. Because of the considerable variation in egg hatching dates and larval development it was agreed that two applications of insecticide at 2 oz./acre would be more effective than one at 4 oz. This procedure would further reduce the possibility of harmful effects of insecticides to fish and wildlife. The meeting was advised by Mr. Flieger of FPL that the insecticide should be ordered by mid-winter to ensure delivery in time for a spray operation in June. NFS authorities assumed the responsibility for procurement of the insecticide pending a decision to spray. Representatives of FPL tentatively agreed to accept responsibility for conducting the spraying operation.

THE SPRAYING OPERATION - 1968

It was not until mid-May 1968 that the NFRC was advised that the Provincial Government had authorized spraying and had let a contract to FPL. The NFS requested the NFRC to undertake surveys to determine the boundaries of areas to be sprayed, to establish the time to start spraying, and to monitor the effectiveness of the operation.

Estimate of Areas Requiring Protection

Planning of the operation required that estimates be made of the location and extent of areas that would need protection in 1968. These estimates were made on the basis of data from fall moth surveys, 1967 outbreak boundaries, stand susceptibility and economic value. Information on the last two factors was provided by the limit holders. Priority classes were then established as follows:

Priority "A" - All defoliated stands, except those marked for salvage, and other mature stands with a high balsam fir content and a high economic value. Stands more than 60 years old containing 60% or more balsam fir, and merchantable stands previously damaged by the balsam woolly aphid were considered most susceptible to attack. Acreages included 73,000 in western; 2,000 in central; and 4,000 in eastern Newfoundland, for a total of 79,000 acres.

Priority "B" - All areas with a high potential for outbreak based on traces of defoliation, heavy moth flights and high susceptibility but of less economic value than in "A" because of distance from the mill, or lower merchantable volume. Acreages included 384,300 in western, 94,300 in central and 4,000 acres in eastern, for a total of 482,600 acres.

Priority "C" - All other stands over 30 years old and containing 25% balsam fir, with a potential merchantable value, with no defoliation and few moths; 240,000 acres.

A total of 801,600 acres was eventually delineated as requiring protection (Fig. 8). However, because of financial limitations only 500,000 acres in Priorities A and B were designated for treatment.

Defining Areas Requiring Protection

The broad estimates of areas requiring protection provided in the fall were tentative. Intensive larval and defoliation surveys* the following spring and early summer were required for the final delineation of areas to be sprayed.

Larval survey - On May 9 a survey was initiated to determine the timing and rate of hatching of looper eggs. This information was required to establish the time for starting a full-scale larval sampling program and for providing an advance estimate of when spraying operations should begin. The survey was conducted by a 2-man crew in infested stands in six major watersheds from North Branch to Serpentine Lake in western Newfoundland. Previous studies suggested that intensive larval sampling should start when 10 or more early instar larvae per

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*Larval sampling systems were devised by Messrs. D.G. Bryant, and G.L. Warren of NFRC.

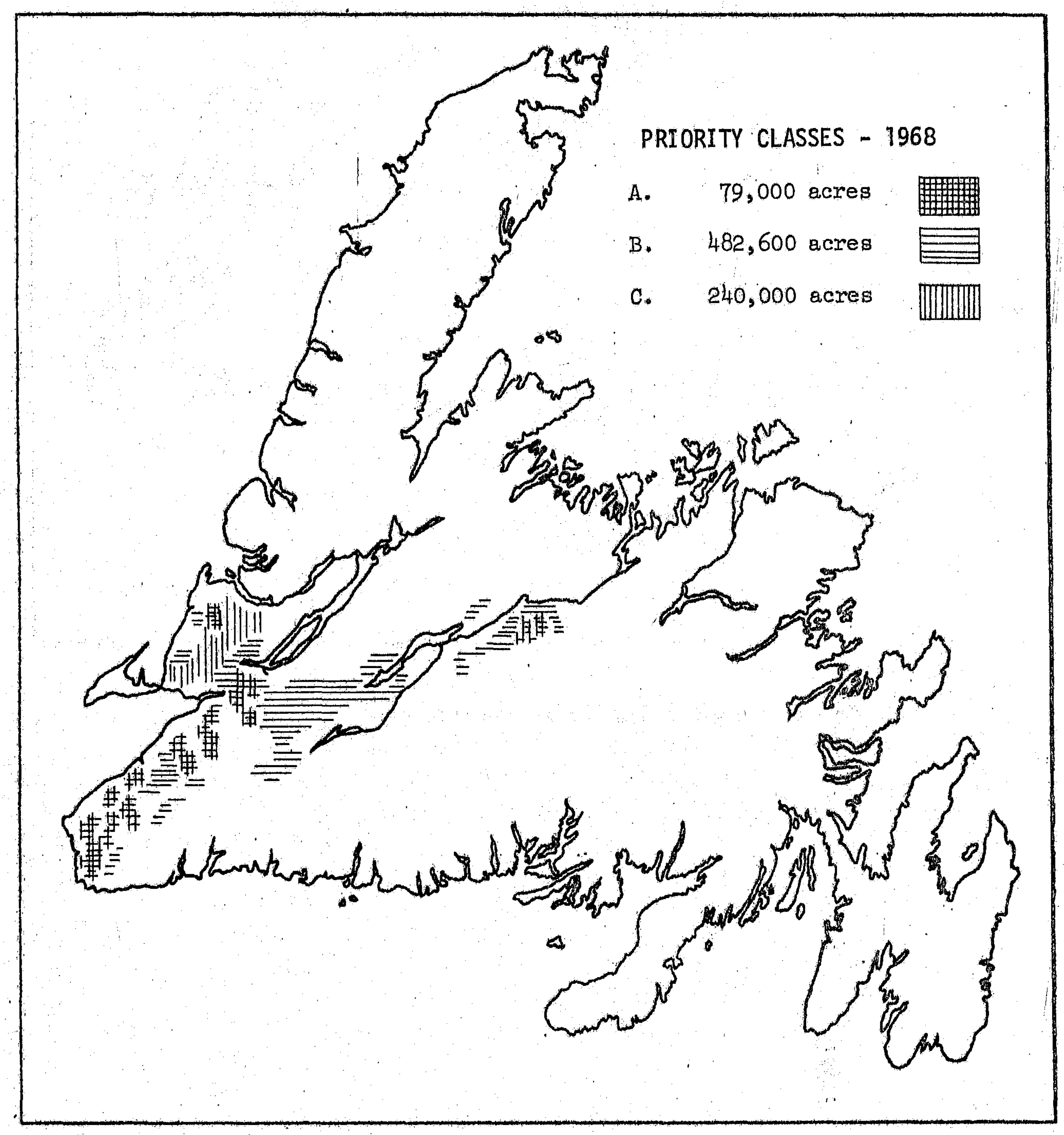

Fig. 8, Areas delineated for protection in 1968.

tree sample were collected. This number was designated as the "significant number" and was also used to identify a looper population level that could cause appreciable defoliation. After hatching of eggs has been completed and about 30% of the larvae are in the 3rd instar, the "significant number" loses its usefulness. At this point samples of 100 or more larvae would have the same meaning, in potential to cause damage, as the 10 larvae from earlier samples. In any event at this later stage estimates of defoliation become more valuable as indicators of infestation intensity and the need for protection.

The first looper larva was found at Crabbs River on June 5 and the first "significant number" at North Branch on June 19. Pre-spray larval sampling was started on June 19 in western Newfoundland and on July 4 in central Newfoundland. The purpose of this survey was to locate infestations, define their boundaries, and determine when specific areas were ready for spraying. Emphasis was placed on areas having "A" and "B" priorities. Three, 2-man road crews and two, 2-man helicopter crews participated. Sampling from helicopters did not begin until June 27 because machines were not available earlier.

Two sampling systems were used by the road crews. In western Newfoundland, three plots, each containing three trees, were sampled at 17 locations. At each location the three plots were spaced at 9-chain intervals along an 18-chain line commencing 2 chains from the roadside. In central

Newfoundland the system was modified to include only one plot containing three trees. However, because of lack of time and manpower, only 13 locations were sampled from the central area. Helicopter crews were required to sample six representative trees at 149 locations (82 in western, 64 in central and 3 in eastern Newfoundland). All samples were collected by beating one side of each tree over a 7' by 9' beating sheet divided into nine equal rectangles. When larvae were numerous (more than 100 per sample) only those in the centre rectangle were counted and the total number was estimated by multiplying by nine. Sampling was discontinued in a plot when one of the trees yielded a "significant number" of larvae. All trees sampled were marked for rechecking following spraying. Standard survey enclosure slips were completed for all samples and the larvae were subsequently reared at survey headquarters to evaluate the incidence of disease and parasites.

A total of 420 trees were sampled in the survey, 281 in western, 128 in central and 11 in eastern Newfoundland. Figure 9 shows the distribution and relative density of samples collected throughout the Island. Pre-spray larval counts are summarized by region and spray priority in Table I. Results show that the average number of larvae per tree was highest in central Newfoundland, and higher in the "A" than either the "B" or "C" priorities, regardless of location. Larval counts in the "A" priority averaged 143.8 in western, 101.0 in central

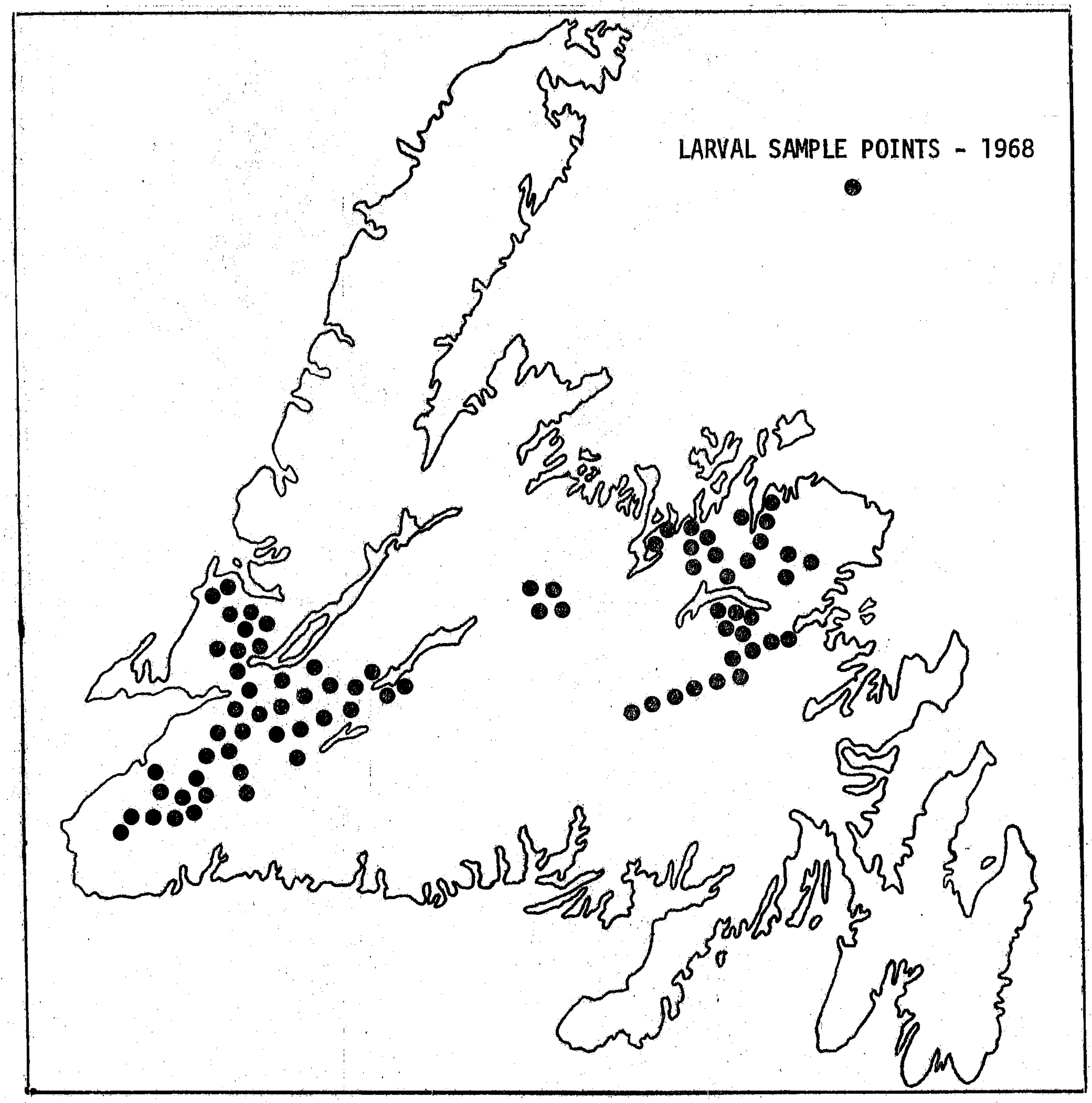

Fig. 9, Distribution and relative density of larval sample points in 1968.

and 11.3 in eastern Newfoundland. One economically important "A" priority area, in the Bottom Brook and Southwest Brook watersheds, was sampled three different times and no "significant number" of larvae was found. The area was not treated and no defoliation occurred.

Defoliation survey - Time and equipment was not sufficient for ground surveys to be conducted in all susceptible stands. Therefore, aerial mapping flights with fixed-wing aircraft were started on July 10 when reddening of foliage became apparent. The survey was terminated on August 3 when spraying was discontinued. The resulting infestation maps were used to adjust spray schedules so that stands with the greatest potential for mortality could be given the highest priority for treatment.

During this survey infested stands were located and mapped at Parsons Pond on the Northern Peninsula; from Serpentine Lake to Grand Lake and between Little Barachois Brook and the Codroy River in western Newfoundland; near Red Indian Lake, Twin Lakes, Gander Lake to Gander Bay South and in the Bay d'Espoir area in central Newfoundland; and at Lady Pond and Cochrane Pond in eastern Newfoundland.

Aerial Spraying

Details of the spray operation have been documented in a report by the NFS (Holmes and Brennan, 1968) and only the highlights are reviewed here. FPL was responsible for preparing spray formulations and for control of spraying aircraft. In

Table I.- Summary of results of 1968 pre-spray larval sampling in Newfoundland.

Spray Priority	Geographic Regions												Total No. sample locations
	Western				Central				Eastern				
	Number of larvae			No. sample locations	Number of larvae			No. sample locations	Number of larvae			No. sample locations	
	Min.	Max.	Av.*		Min.	Max.	Av.		Min.	Max.	Av.		
A	0	2012	143.8	23(83)**	0	1152	101.0	65(88)	0	6	11.3	3(11)	91(182)
B	0	1802	21.4	76(195)	0	500+	28.7	14(40)	0	0	0	0	90(235)
C	0	0	0	1(3)	0	0	0	0	0	0	0	0	1(3)
Island Wide	0	2012	57.3	100(281)	0	1152	78.5	79(128)	0	6	11.3	3(11)	182(420)

*Average number of larvae per tree
**Number of trees sampled shown in parenthesis

western Newfoundland two insecticides were used; phosphamidon near the major water systems, because of its lower toxicity to aquatic life, and fenitrothion in other areas. Only fenitrothion was available for use in central Newfoundland. Insecticides were applied by eight Grumman Avenger aircraft guided by Cessna "pointers".

Initially the operation was based at Stephenville airport and spraying began on July 9. By July 23, 223,000 acres, in western Newfoundland, had been treated with two applications of insecticide at 2 oz./acre at 6- to 8-day intervals. An additional 72,000 acres were treated on July 24 with one application at 4 oz./acre. The latter heavier dosage was used because by this time light to moderate defoliation had occurred and larvae were in the more destructive late instars. As the larger larvae were also more resistant to the insecticide it was apparent that there was insufficient time to follow the prescribed two-application procedure. Therefore, the dosage was doubled to 4 oz. in one application, in an attempt to limit damage. A similar situation occurred in central Newfoundland when on July 21 defoliation was observed in the Gander area. The operation was moved from Stephenville to Gander Airport on July 26 and from here 136,000 acres were treated with a single application of fenitrothion at 4 oz./acre. This operation was completed on August 3. A total of 431,000 acres were treated (Fig. 10).

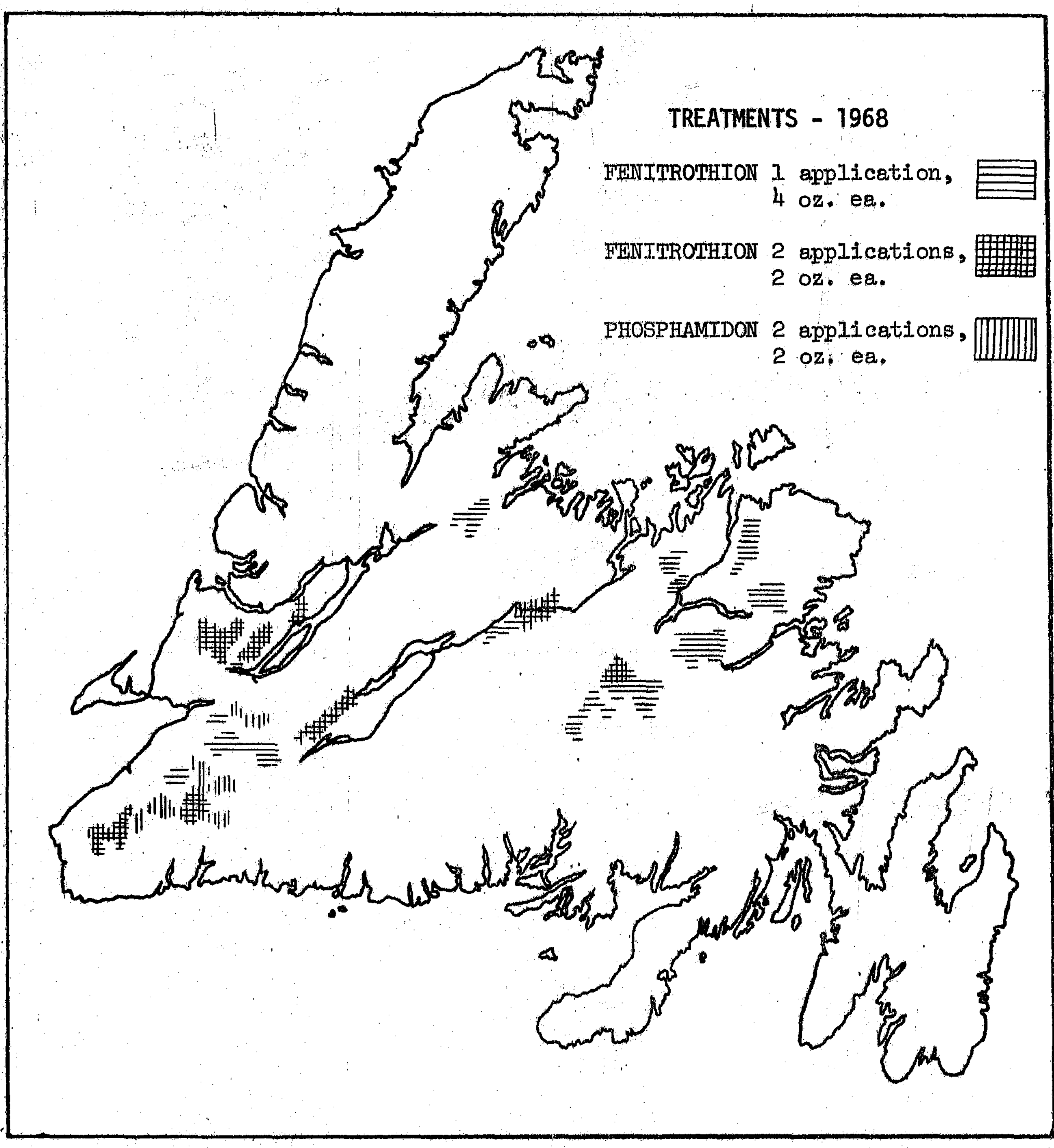

Fig. 10, Areas sprayed in 1968.

During the operation several attempts were made by the NFRC to determine the intensity of spray application by distributing spray droplet monitoring cards in areas designated for treatment. These were unsuccessful as areas to be sprayed were often not treated as scheduled, and cards could not be left overnight because dew or rain made them unsuitable for interpretation.

Effectiveness of Spraying

Three methods were used to determine the effectiveness of the spray operation. Surveys were conducted to estimate the numbers of looper larvae killed, and later in the season to estimate numbers and distribution of moths. An aerial survey was also conducted to map outbreak boundaries and estimate the intensity of damage.

Larval survey - Samples were taken in areas with high population levels and only from the opposite sides of trees sampled prior to treatment. In western Newfoundland 39 locations were checked by three, 5-man road crews. An additional 15 samples were collected from inaccessible sprayed acres in western and central Newfoundland, by a 2-man helicopter crew. Sampling was done between July 23 and 27 in western and on August 14 in central Newfoundland. Trees were sampled 6 to 12 days after spraying. Standard survey enclosure slips were completed and in the "remarks and symptoms" section the larval condition, at the time of sampling, was recorded. All samples were sent to survey headquarters at St. John's for rearing and observations on mortality. Pre- and post-spray larval counts by region are summarized in Table II.

Table II.- Summary of pre- and post-spray larval surveys of plots sprayed in 1968.

Region	Insecticide	Application	No. of post-spray samples	Av. no. of larvae/tree pre-spray	Av. no. of larvae/tree post-spray	Percent reduction
Western	Not sprayed	-	11	460	1,022	An increase of 122.2
Western	Phosphamidon	2 oz./ac. x 2	6	921	16	98.3
Western	Fenitrothion	2 oz./ac. x 2	30	220	29	86.8
Central	Fenitrothion	4 oz./ac. x 1	7	448	171	61.8

Data show that larval numbers increased by more than 120%, between pre- and post-spray sample periods, in untreated areas; hatching was not complete when the pre-spray samples were taken. However, numbers decreased appreciably in treated areas. The highest reduction, 98%, occurred in areas treated with phosphamidon as compared to 87% in areas treated with fenitrothion. The latter was the only insecticide applied in both single and double dosages. It appears that two treatments at 2 oz./acre each were more effective than the single treatment at 4 oz./acre. However, the single treatment was applied later in the season when looper larvae were in the more resistant advanced instars.

Defoliation survey - This survey was conducted following the larval feeding period. Fixed-wing aircraft were used and all forested areas of the Island were examined between September 4 and 11. The boundaries of looper infestations were recorded on 1:250,000 scale maps and the intensity of defoliation was estimated as light, moderate or severe (light 0-25%; moderate 26-50%; severe 51-100%).

The survey showed extensive damage to fir stands throughout the Island. Light to severe defoliation was recorded in 207,790 acres in western, 342,660 in central, and 16,900 in eastern Newfoundland, giving a total of 567,350 acres, an increase of 446,760 acres over 1967 (Fig. 11). Tree mortality was greatest in areas with a long history of damage by the balsam woolly aphid. Defoliation was negligible in several sprayed areas, especially in those treated when the larvae were in the early instars. Conversely, defoliation was obvious and frequently severe in unsprayed areas or in those where the spray was applied after the larvae had reached the 3rd or 4th instars. This condition occurred most frequently in central Newfoundland where, because of operational difficulties, spraying was not conducted until the later part of July and early August.

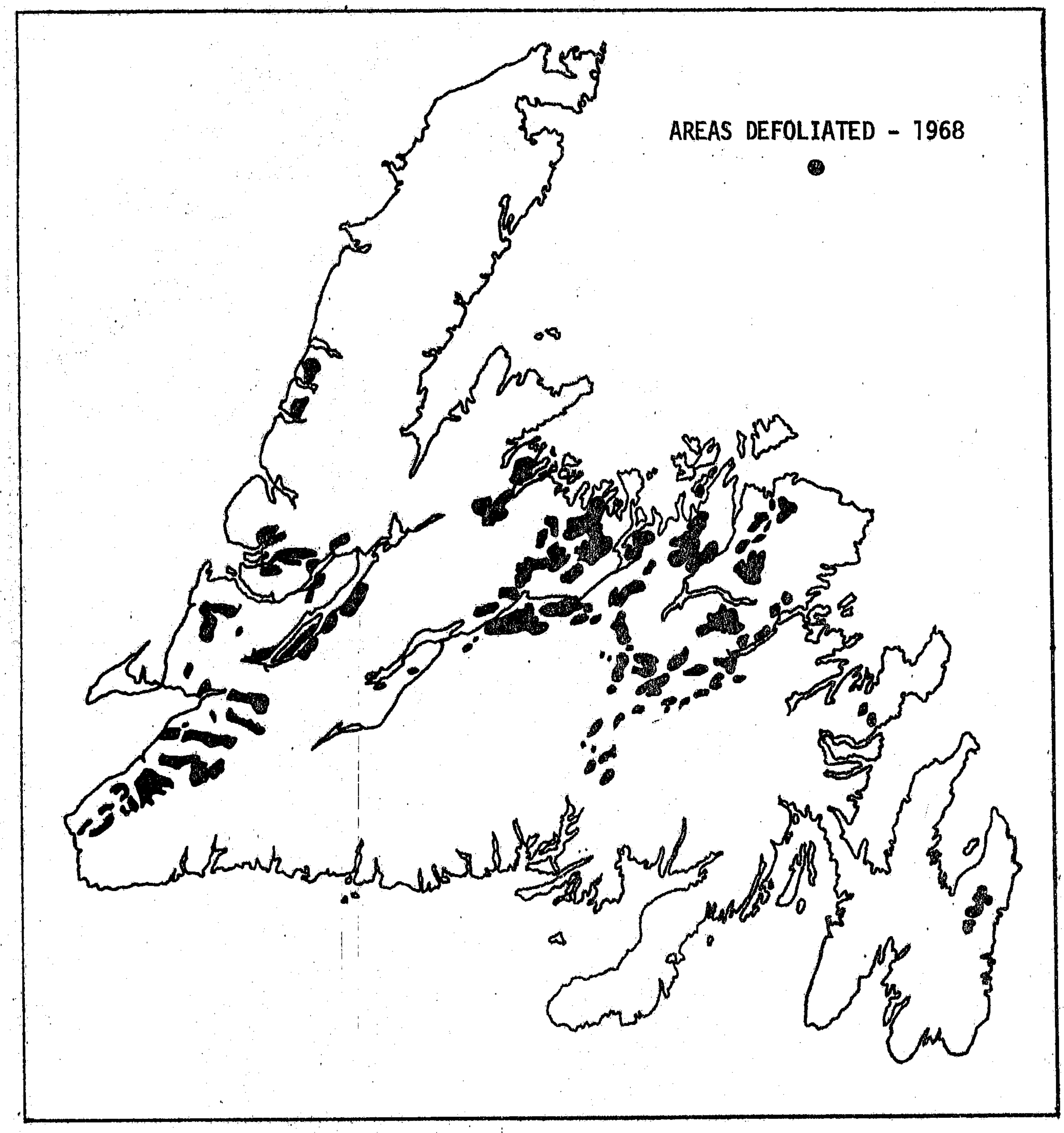

Fig. 11, Areas defoliated by the hemlock looper in 1968.

Defoliation occurred on one-third or 139,300 acres of the treated area and was severe on 33,570 acres. About one-half of the infested but untreated area, 428,000 acres, was severely defoliated. It is evident that the spray operation was effective; it reduced the size of the infestation and the intensity of defoliation.

Moth survey - This survey was conducted between October 2 and 11 by two, 2-man road crews and one, 2-man helicopter crew. A total of 150 locations were examined in both defoliated and undefoliated stands. Reports of moth occurrences were also provided by personnel of the two paper companies and the NFS. The distribution and density of moths were determined by beating the loose bark of birch trees, and underbrush. The fluttering moths were estimated as numerous (20 or more), few (1-20), and none (0).

Moths were numerous in both the treated and untreated stands between Grand Lake and Serpentine Lake, the Humber River watershed and the Goose Arm area of western Newfoundland; and in the Twin Lakes, Exploits Valley and Bay d'Espoir areas of central Newfoundland. Very few were reported in the untreated watersheds between North Branch and Bottom Brook and on the Baie Verte Peninsula. No survey was conducted on the Northern or Avalon peninsulas.

Problems Encountered

There are many problems to be solved in planning and conducting an aerial spray operation to control a forest insect. Initially, the limit holder must decide if it is more economical to concentrate on pre-salvage and salvage harvesting than on providing protection by spraying. Decisions must be reached on whether stands have a high enough commercial value, by reason of accessibility or yield potential, to justify protection costs. Planning must ensure that an acceptable insecticide and suitable aircraft are available in sufficient quantity to complete the operation. Knowledge of the biology and behavior of the insect is important for timing the spray period, and the spray interval if more than one application is to be used. Efficient surveys are required to designate the areas requiring protection and to monitor the effectiveness of the spray. Obviously such a complex operation requires intensive planning, close co-ordination between involved agencies, and a high level of competence in all aspects of the program.

Many problems were encountered during the 1968 operation. These were caused primarily by inexperience because it was the first operation of its kind undertaken in Newfoundland. Consequently, it was not conducted as efficiently as was desired. Details of some of the principal difficulties encountered are given below:

The decision to conduct a spray operation was reached too late for efficient planning. The NFRC was not notified until mid-May that a spraying operation would be undertaken. This meant only a 2-week period to plan the required surveys, and acquire the aircraft necessary to conduct them.

The lack of a program director with decision-making authority to control and direct the operation. The absence of this authority resulted in poor communication and co-ordination between participating agencies.

The unavailability of helicopters when required. Efficient surveys could only be conducted using this type of aircraft because of the inaccessibility of many susceptible stands. It was estimated by NFRC that three helicopters would be required for a 1-month period. Only one company held a franchise to operate helicopters in Newfoundland and would only consider a 6-month charter for each aircraft, making the cost prohibitive. Attempts to obtain the use of helicopters from the Department of National Defense, the Department of Transport, and the Fisheries Service were unsuccessful. The NFS finally offered to guarantee the required helicopter service, including the use of a "standby rescue" helicopter, and this offer was accepted. However, considerable difficulty was experienced with this arrangement, when aircraft were often recalled for fire protection duties or other commitments. The "standby rescue" helicopter was not available once spraying started.

The lack of enough spray aircraft to complete the operation before damage became serious. The optimum period for spraying is only about 25 days, from about 3 days after the first "significant number" of larvae to when 30% are in the 3rd instar; this includes the major period of larval development, before severe defoliation occurs. Less than 2/3 of the days during this period are likely to be suitable for spraying because of adverse weather conditions. Much of the spraying in Newfoundland was conducted after the optimal period when defoliation was frequently severe and the larger larvae were more difficult to kill. Consequently, the protection provided by the spray operation was less efficient than expected. This was particularly serious in the central region where spraying commenced July 26 and most of the larvae were in an advanced stage of development. Some infested stands were already severely defoliated.

The impossibility of obtaining accurate fall forecasts of the size and intensity of infestations to be expected the following summer. A reliable method of sampling populations of moths or eggs, the stages occurring in the fall, has not been developed. Experience in the current outbreak showed that numbers of moths were not always an indicator of population levels to be expected the following year.

The unavailability of forest type maps, showing stand composition and age classes. This made it difficult to define stand hazard ratings and to plan an adequate distribution of sampling locations. Inventory records of the forest agencies were used, but were not always accurate or complete. Also, areas delineated as unsusceptible to looper attack, because the stands were immature, often contained scattered blocks of susceptible mature trees left from previous cutting. Presumably, at the time of cutting, these blocks were either unmerchantable or inaccessible. They now became epicentres for infestations that extended into the adjoining immature stands.

The difficulty in defining spray boundaries over an extensive area. The wide distribution and irregularity of areas susceptible to looper attack, the time-consuming larval sampling procedures and the short period suitable for larval surveys before spraying, made it impossible to define precisely the boundaries of areas requiring protection.

The lack of a composite operational map. Control headquarters lacked a composite map delineating forested areas, their priorities for treatment, the distribution and intensity of infestations, and areas sprayed or scheduled for spraying. Consequently, much valuable time was lost searching for information that should have been recorded on such a map and, therefore, immediately available. This situation created unnecessary confusion and tension among operating personnel.

The lack of confidence by controlling agencies in the advice provided by local specialists. This problem became most acute when looper conditions in central Newfoundland dictated that the spray dosage should be increased and priorities adjusted. Consequently, there was considerable delay in reaching important decisions.

The lack of financial and manpower resources. The limitation on funds available to NFRC made it impossible to conduct the detailed surveys required to determine precisely the distribution and extent of the outbreaks. This inflexibility, in the redistribution of budgeted funds, was characteristic of all agencies in contrast to a very flexible attitude, when faced with a known crisis situation, e.g. a forest fire. No doubt the major problem was a lack of understanding of the destructive potential of the hemlock looper.

The lack of a method for monitoring effectiveness of spraying. It was impossible to achieve any precision in monitoring the effect of spraying. Part of the problem was caused by not having enough survey crews and helicopters for an intensive post-spray larval survey. An equally important limitation was the inability to measure the amount and distribution of spray being deposited on the foliage. The spray droplet cards were impractical for use in the Newfoundland operation.

The lack of an adequate system for relaying data from field survey crews to control headquarters. There was often confusion at spray headquarters in interpreting data obtained from survey crews. This was partly because names of topographic features were used in identifying specific areas and it was difficult to determine the precise location of a sample. The problem was further complicated when different topographic features had the same names. The result was needless duplication in flying, to check on conditions already surveyed.

THE SPRAYING OPERATION - 1969

Planning for the 1969 spraying operation was initiated as soon as data from 1968 fall surveys became available. Unlike in 1968, it was recognized very early that severe outbreak conditions would occur in 1969 and that another spraying operation would be necessary to protect the infested stands. All agencies agreed that in order to avoid a repetition of the administrative difficulties encountered in 1968 a Task Force should be organized and made responsible for planning and controlling the operation.

The Task Force

The Task Force was comprised of four members, one from each of the two major companies, Bowaters and Price, and one from each of the NFS and the NFRC. The member from the NFS was the Chairman and Head of the Force. Voting rights on decisions affecting the operation were held only by the land owners Bowaters, Price, and the NFS. Advisors from the Fisheries Service, Newfoundland Wildlife Service, CCRI, FPL, CIBA and the Canadian Wildlife Service, attended the meetings when needed.

A total of 21 meetings were held between December 18, 1968 and November 13, 1969. The meetings were concerned primarily with developing administrative and operational procedures, assigning responsibility for specific tasks and ensuring that satisfactory progress was being made. The responsibilities of the Task Force were many and varied and included such items as arranging accommodations and meals for spray crews, selecting airfields, the safe handling and storage of insecticides, and disposal of containers. The Force was allocated an operating budget by the Provincial Government not to exceed 2 million dollars. The costs of NFRC activities,i.e. the detection and delineation of boundaries of infested areas, an evaluation of the effect of spraying on looper numbers, and the forecasting of conditions for 1970 were not included in this amount. The NFRC was also required to advise on biological aspects of the project including the timing and dosages of the insecticides. The spraying contractor was responsible for delineating boundaries of spray blocks in areas selected for treatment.

Estimate of Areas Requiring Protection

Surveys in the fall of 1968 had shown that the outbreak had collapsed in many of the areas treated, but was expected to be much more extensive in other areas. The total forecast area of infestation for 1969 was initially estimated at about 3,000,000 acres, more than half of which, 1,750,000 acres, was in central Newfoundland. The NFRC provided limit holders with 1:250,000 scale maps of Newfoundland showing 1968 outbreak boundaries and hazard ratings for other areas. The limit holders then delineated areas for protection using the "A, B, C" priority classification devised in 1968. This information was then collated and transferred to a single 1:250,000 scale map of the Island. When priorities differed at limit holders boundaries adjustments were made by the Task Force to provide a common priority for a forested area. The final estimate of areas designated for protection was over 4,000,000 acres, distributed by priorities as follows: "A", 2,154,900; "B", 1,293,300; "C", 885,000 (Fig. 12). The Task Force decided that because of budget limitations not much more than 2,000,000 acres could be treated and emphasis would naturally be assigned to the "A" priority.

Defining Areas Requiring Protection

As in the 1968 operation the final determination of infested areas could not be made until surveys were conducted in the summer of 1969. During the winter detailed plans were made for larval sampling and for communicating results of surveys from the field to spray headquarters. It was recognized that sampling by road crews would be impossible because of the inaccessibility of many infested areas. Therefore, helicopters were essential to conduct the survey. Experience had also shown that the "Chief Ranger", who directed the survey, should have complete control of the scheduling of survey aircraft. Negotiations were started early in the winter to charter three helicopters for one

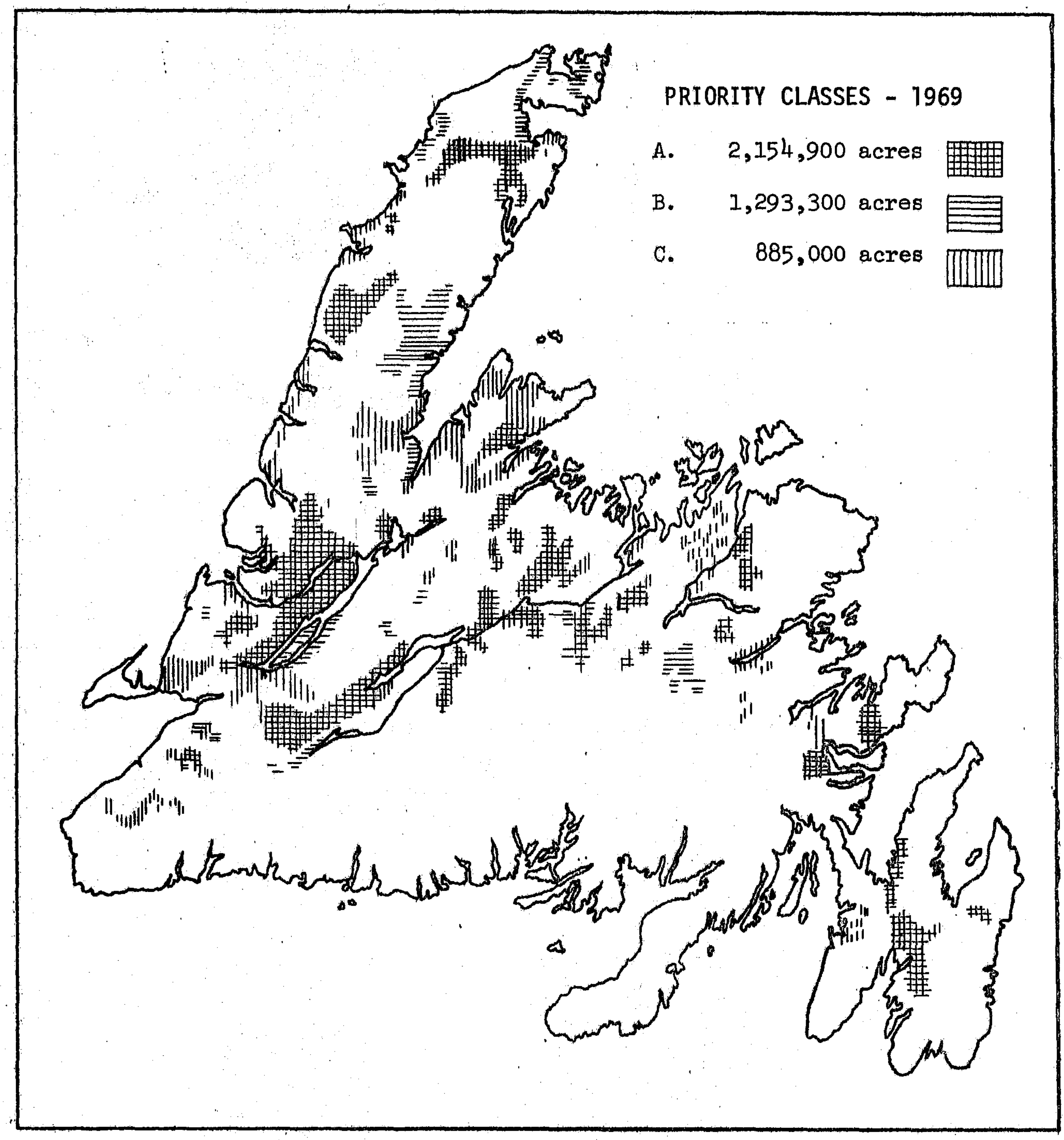

Fig. 12, Areas delineated for protection in 1969.

month each. These were unavailable locally and a contract was finally arranged with Maritime Air Service Ltd. of New Brunswick, but only after a franchise for this company to operate in Newfoundland had been obtained from the Air Transport Board.

Larval survey - Detailed planning of the larval sampling procedures occupied most of the winter period for the Forest Insect and Disease Survey staff of NFRC. Survey records indicated that there were only 25 days from collection of the first "significant number" of larvae, i.e. 10 larvae per tree sample, to the time when defoliation would be apparent from aircraft, after which it would be more practical to conduct defoliation surveys. Experience from 1968 showed that of the 25-day period only about 15 days could be utilized for sampling because of aircraft maintenance requirements and adverse flying conditions. It was estimated that each survey crew could collect 16 samples per day; a total of 720 samples, for the three survey crews, in 15 days. The 720 samples were then allocated by priorities as follows: "A", 480 samples, i.e. one per 4,500 acres; "B", 160 samples, i.e. one per 8,000 acres; "C", 80 samples, one per 12,000 acres. This distribution weighted sampling towards the highest priority areas but also provided that the lowest priority contained at least one sampling point per spray block of 12,500 acres. Priority boundaries, originally delineated on 1:250,000 scale maps, were transferred to 1:50,000 scale map sheets. The sample points were then selected and marked on these map sheets.

It was necessary to use the 1:50,000 scale maps in the survey because they contained the topographic information required for selecting helicopter landing sites near stands to be sampled. Aerial photographs were also used to assist in the location of the sample positions.

The problem of relaying information accurately from field crews to spray headquarters was resolved by using the numerical coding system of the Universal Mercator Grid applied to 1:50,000 scale map sheets (Ann. 1969). During the operation data were relayed by radio-telephone to the survey "director" who then transferred it to the 1:250,000 scale operations map. The latter was a more convenient size for use by the Task Force for planning and decision making, and helped to avoid some of the confusion experienced in the previous year.

As in 1968, a survey was conducted to determine the timing and rate of development of hemlock looper larvae. This survey started on June 2 in western Newfoundland. The first larva was found on June 9 at South Brook Valley and the first "significant number" was collected on June 10 at Goose Arm; the first "significant numbers" were found on June 17 in central and eastern Newfoundland.

Pre-spray larval sampling was initiated as helicopters became available, on June 16 in western, June 22 in central, and June 26 in eastern Newfoundland. Data from 1968 had indicated that two trees provided an adequate sample. These two trees were sampled by beating one side only. The opposite side was reserved for post-spray larval sampling. Larval population levels were expressed as an average number of larvae per tree sample. Additional sampling was conducted in 11 areas where "significant numbers" of larvae were not obtained during the first 10 days of sampling. A total of 744 samples were collected; 544, 163, and 37 in priority classes "A", "B", "C" respectively (Fig. 13). All larvae collected were sent to the laboratory for rearing.

Results of sampling indicated low larval numbers in all priority areas south of Serpentine Lake and on most of the Baie Verte, Bonavista and Avalon peninsulas. Larval numbers were high in a 60,000-acre area near Portland Creek on the Northern Peninsula. Most other "A" and "B" priority areas showed potentially dangerous population levels, with the highest numbers of larvae occurring in central Newfoundland (Table III). Stands sprayed in 1968 near Serpentine Lake had an exceptionally high moth count in the fall. However, these stands were sampled three times in 1969; larval numbers were very low, and no damage occurred.

Defoliation survey - In 1969 larval development was about a week earlier than in 1968. Therefore, aerial surveys from fixed-winged aircraft were initiated on July 2, 8 days earlier than in the previous year. The first reddening of foliage became evident on July 6, 4 days earlier than in 1968.

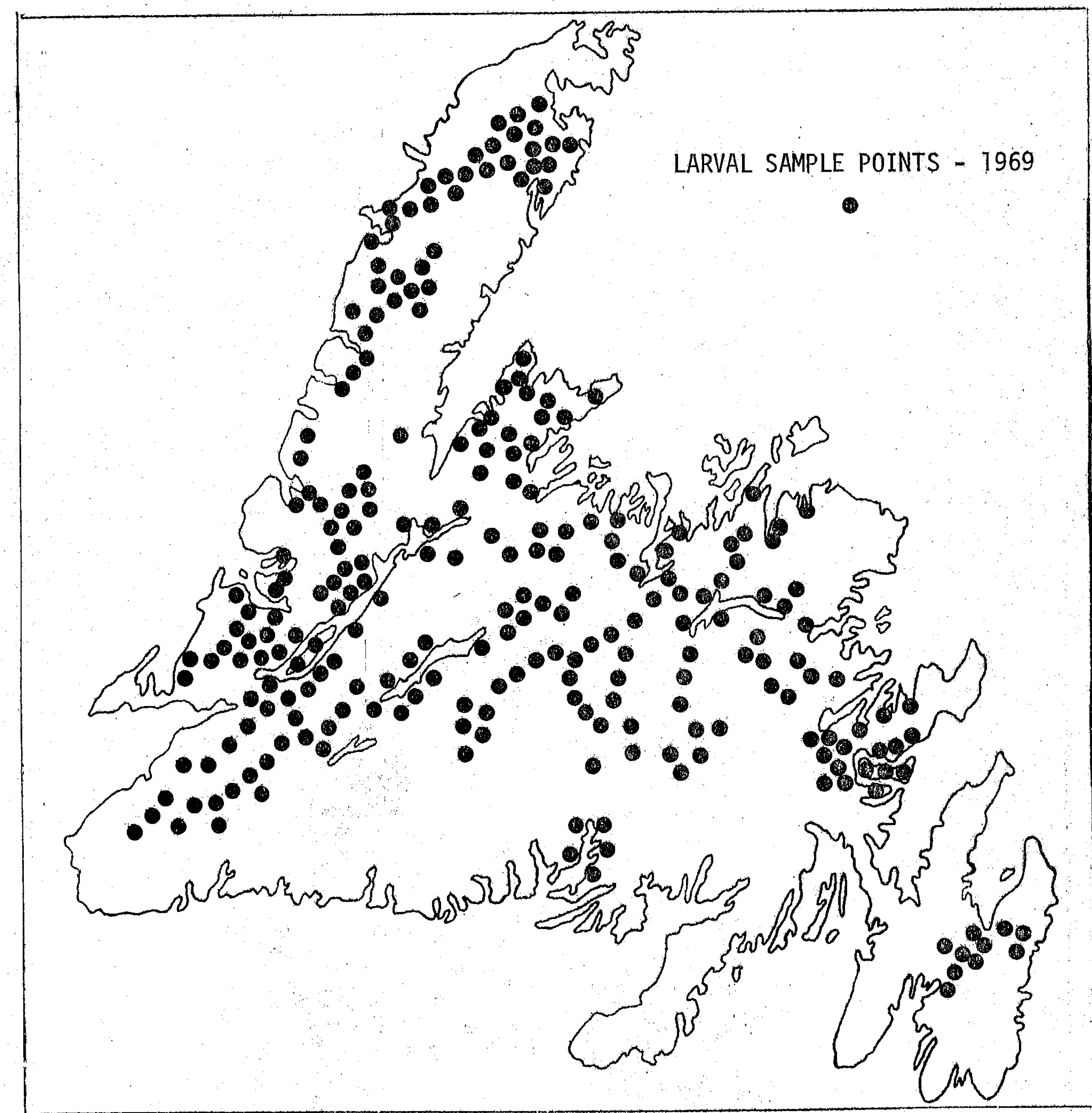

Fig. 13, Distribution and relative density of larval sample points in 1969.

During this survey infested stands were mapped in the Grand Lake watershed in western Newfoundland, and at Sheffield Lake, the Badger area, Norris Arm and Southwest Gander in central Newfoundland.

Aerial Spraying

Details of the 1969 spray operations have been documented in a report by the NFS (Holmes, 1970). Only a few of the more significant aspects are reviewed here. The contracting company, FPL, was again responsible for preparing formulations and controlling spray aircraft. Fenitrothion and phosphamidon were the insecticides used. They were applied principally by 18 Grumman Avenger and two DC-3 aircraft, guided by Cessna "pointers". The 60,000-acre area near Portland Creek was sprayed by a Pilatus Porter aircraft equipped with a Decca guidance system. Spraying operations began on June 28 at Deer Lake, July 3 at Gander, July 18 at Portland Creek and July 26 at Stephenville. Headquarters for the entire operation was at the Holiday Inn, Gander, but the control centre for western Newfoundland was at Deer Lake.

Spray dosages were essentially the same as in 1968, i.e. two applications of 2 oz./acre each at 7-day intervals. On July 9 when 30% of the larvae were in the 3rd instar, and defoliation had become evident, the NFRC recommended that the interval between treatments be reduced from 7 to 4 days. However, adverse weather conditions prevented spraying until July 15 at

Table III.- Summary of results of 1969 pre-spray larval sampling in Newfoundland.

Spray Priority	Geographic Regions												Total
	Western				Central				Eastern				
	Number of larvae			No. sample	Number of larvae			No. sample	Number of larvae			No. sample	No. sample
	Min.	Max.	Av.	locations	Min.	Max.	Av.	locations	Min.	Max.	Av.	locations	locations
A	0	400	5.5	281(572)	0	1200	37.6	208(412)	0	850	8.5	55(114)	544(1098)
B	0	532	8.8	125(258)	0	1200	59.5	19(38)	0	225	15.9	19(36)	163(332)
C	0	19	1.3	15(30)	0	180	16.6	14(27)	0	13	2.8	8(16)	37(73)
Island Wide	0	532	6.3	421(860)	0	1200	38.1	241(477)	0	850	9.5	82(166)	744(1503)

which time 70% of the larvae were in the 3rd instar. Defoliation was becoming severe in some areas and recommendations were made to increase the dosage from 2 to 3 oz./application, to treat the most heavily infested stands first, and where feasible to reduce the interval between applications to one day. This advice was accepted and followed. A total of 2,054,900 acres were treated; 1,659,400 in "A", 328,600 in "B" and 66,900 in "C" priority (Fig. 14). Fenitrothion was used in all areas except for 60,000 acres on the Northern Peninsula, and 44,000 acres in central Newfoundland where phosphamidon was used. Spraying was completed on July 27.

No large scale attempt was made to monitor the intensity and distribution of insecticide deposited in 1969 because of difficulty experienced in 1968. However, spray droplet cards were distributed, prior to spraying in South Brook Valley, an area selected for an intensive study of the hemlock looper. The cards were distributed immediately prior to two scheduled spray applications. Of the cards in the open 52% received some spray deposit in the first treatment and 93% in the second, suggesting that about one-half the area was missed in the first instance (Otvos and Carter, 1970).

Effectiveness of Spraying

Methods used to evaluate the effectiveness of the spray operation were essentially the same as in 1968 and included surveys to determine numbers of larvae and moths present, and the extent and intensity of defoliation.

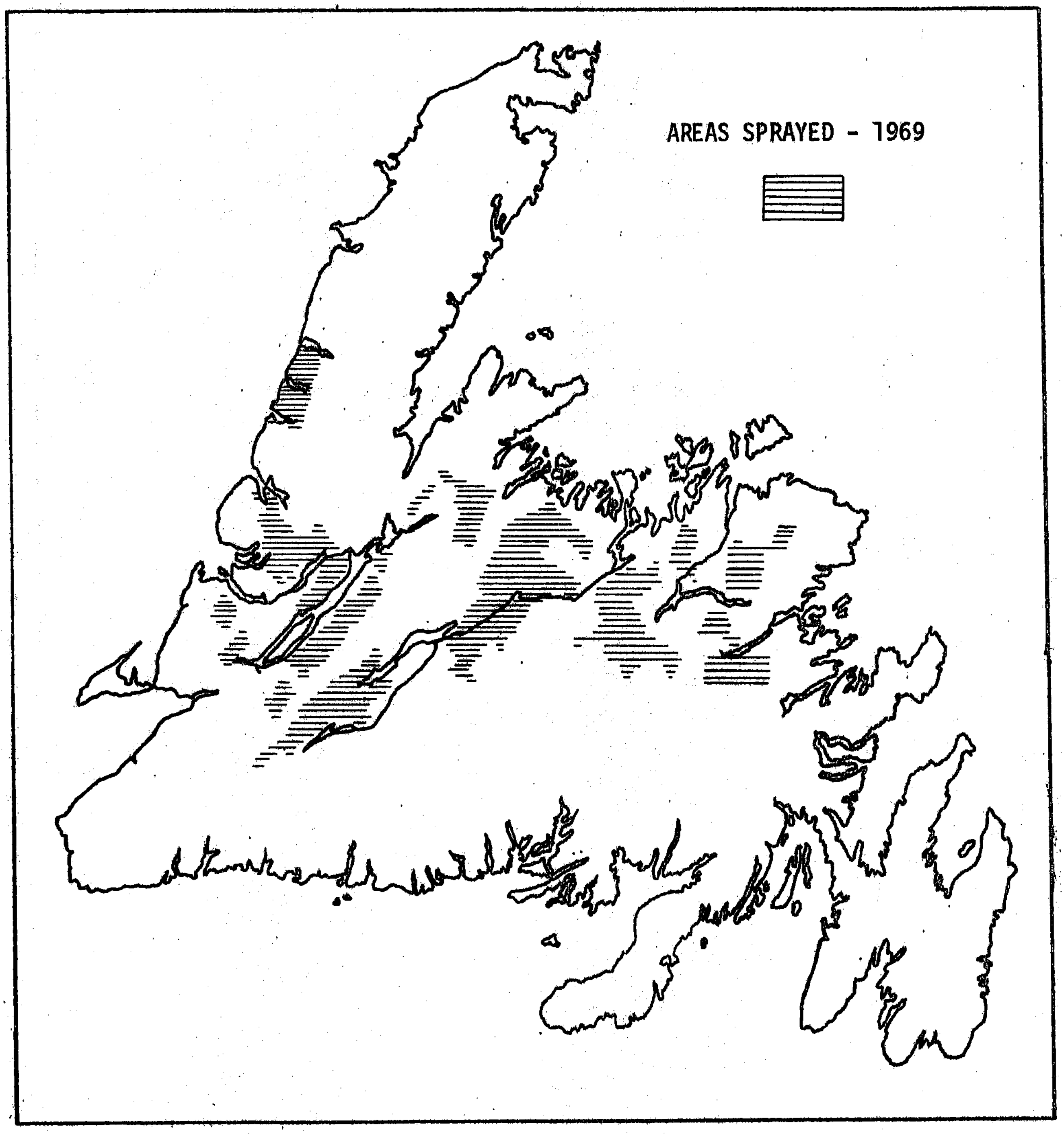

Fig. 14, Areas sprayed in 1969.

Larval survey - Samples were collected from 66 locations, 15 after the first application of insecticide, and the remainder after the second. At each location four samples were collected, one from the opposite side of the two trees sampled in the prespray survey, and one from each of the two previously undisturbed trees. It was impossible to make any precise interpretation of the results because dosages and numbers of spray applications differed, sampling was not intensive enough, and survey schedules were impossible to maintain. However, certain trends were indicated and are illustrated by the following examples.

Fenitrothion gave better control than phosphamidon, a 94% reduction in larval numbers as compared to 80%. One application of fenitrothion of 2 oz./acre reduced larval numbers by 85%, whereas two applications of 2 oz./acre each reduced them by about 96%. The same reduction in larval numbers was obtained with an application of 2 oz./acre followed by a second at 3 oz./acre. However, in the latter case the larvae were in later instars and, therefore, more difficult to kill. No results were obtained from treatments involving single applications of 3 oz./acre or two applications of 3 oz./acre. In a special study at South Brook Valley it was determined that larval mortality following spraying was highest among 1st and 2nd instar larvae. Two applications of fenitrothion reduced larval population levels by about 90%, 6 days after the second spray and by 96% on the 12th day. These results compare favorably with the average of 94% determined from Island-wide data collected in the survey. Data from the survey also showed that the two trees used in pre-spray sampling were adequate for the post-spray survey and that the addition of undisturbed trees was unnecessary. Experience also showed that precise information on effectiveness of spraying can only be obtained by experiments conducted independently of an operational program. Regardless of these results it is recommended that post-spray checking be conducted in any future operation to provide an evaluation of the effectiveness of the spray.

Defoliation survey - This survey was started on August 20 and completed August 29 except for the Bonavista and Avalon peninsulas which were examined in September. Fixed-winged aircraft were used to map the boundaries and intensity of 1969 defoliation and the classification system was the same as that used in 1968. The survey showed that no defoliation occurred in 1969 in watersheds south of Corner Brook that had been heavily infested and sprayed in 1968. Included in the area were stands at Serpentine Lake, where high moth counts had been recorded the previous fall but, where few or no larvae were collected in 1969. No defoliation developed in the central Newfoundland areas, Gander Bay South, Jonathon's Pond and Weir's Pond, which had been heavily infested and sprayed in 1968.

A total of over 2,000,000 acres of heavily infested stands were sprayed and of this area defoliation occurred in 433,000 acres. However, reddening was evident in many of these damaged stands before they were sprayed. Damage was also recorded in an additional 300,000 acres of unsprayed forest bringing the total area defoliated to 733,000 acres (Fig. 15). The major new areas of infestation were at Lake Ambrose, Rainy Lake, Round Lake and Bay d'Espoir in central Newfoundland.

Defoliation occurred on one-fifth, or 442,300 acres, of the untreated area and was severe on 90,300 acres. About two-thirds of the infested but untreated area, 183,200 acres, was severely defoliated. Of the 954,100 acres with a potential for defoliation about one-third, or 293,400 acres, were defoliated. It is evident that the spray operation was effective; it reduced the size of the infestation and the intensity of defoliation.

Moth survey - Poor weather conditions restricted moth surveys. However, all major forest areas, except the Bonavista Peninsula, were examined. Moths were abundant in most of the defoliated areas as well as in undefoliated stands in the Bonne Bay - Trout River area and from Western Arm to Chain Lakes on the Baie Verte Peninsula. No moths were observed in undefoliated stands on the Avalon and Northern peninsulas, or on the northern half of the Baie Verte Peninsula.

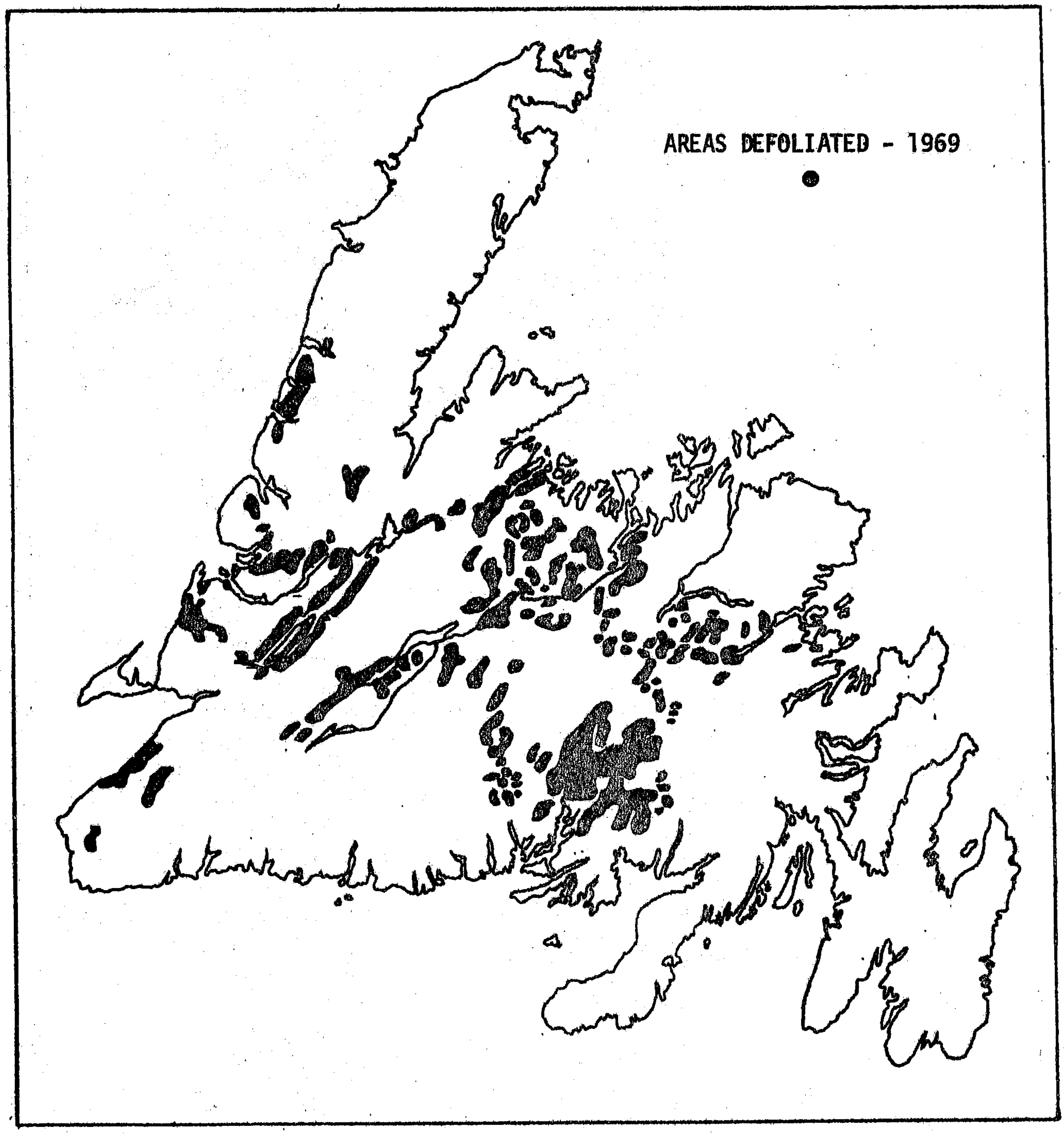

Fig. 15, Areas defoliated by the hemlock looper in 1969.

Problems Encountered

The problems encountered in the 1968 operation have been discussed in a previous section of this Report. In 1969 improvements were made where possible to correct some of these earlier mistakes. The formation of the Task Force, as a controlling and co-ordinating authority, was perhaps the most effective measure taken. A numerical coding system was adopted, for relaying information from field survey crews to control headquarters, thus reducing the possibility of error. A composite operational map, for continuous plotting of looper conditions and progress in spraying, was used to facilitate prompt decision making by spray control personnel. Greater efficiency in the pre-spray survey program was achieved by revisions in survey procedures to give a more uniform distribution of samples, a reduction in size of the sampling unit, and unrestricted control of helicopters by the Survey. Financial and manpower resources available to NFRC had also improved greatly over 1968.

Some problem situations were not as readily resolved and continued to affect the efficiency of the 1969 operation. It was still impossible to provide reliable fall forecasts of looper distribution and population levels expected the following summer. This problem was caused primarily by the lack of a reliable method of sampling looper eggs and moths and because of the characteristic pattern of outbreaks and the extensive areas involved. It may be virtually impossible to ever develop, or even apply, a practical method for fall sampling of this insect. Fall and winter planning was again hindered because forest type maps were unavailable. Although the number of spray aircraft was tripled in 1969, severe damage occurred in some sprayed areas because aircraft were not ready for spraying when required and some areas were treated late. Attempts at monitoring the effectiveness of the spraying operation remained essentially the same as in 1968. The post-spray surveys failed to give consistent and precise results, although a reduction in larval numbers was evident in most cases. However, because of the lack of a practical method of determining the amount of insecticide deposited it was impossible to be sure if this reduction was caused by spraying disease or some other factor.

EFFECTS OF SPRAYING ON FISH AND WILDLIFE

The Fisheries Service conducted experiments, in 1968 and 1969, on the effect of the insecticides on fish populations. The experiments were conducted in areas which had been treated with 2 applications of fenitrothion each year, at the rate of 2 oz./acre. One plot accidentally received a third application, at 3 oz./acre, in 1969. Effects of the spray were evaluated by determining the mortality of "caged and wild"fish, and by sampling and analyzing the bottom fauna, the water, the drifting insects, and the fish, for insecticide content. Results were presented at the 1968 and 1969 meetings of the Interdepartmental Committee on Forest Spraying Operations (Cowley, 1968 and Pond, 1969), and also in a publication (Hatfield and Riche, 1970). The highlights of the experiments are summarized below.

Mortality among the "caged" fish was insignificant in both years. Some mortality was noted among "wild" salmon parr and trout in 1968 but none in 1969. Fenitrothion can reach relatively high concentrations in the stomachs of fish but it "breaks down" rapidly and does not invade the flesh in appreciable quantities. None of the insects analyzed in 1969 showed insecticide content, and only one bottom fauna sample contained insecticide. There was a decline in the number of bottom invertebrates, and an increase in the number of drifting insects (many were dead), following the 1968 operation. However, there was no reduction in the population levels of these aquatic inverterbrate after the 1969 operation. In summary, the results showed that undesirable effects of the insecticide fenitrothion, on fish and aquatic insect populations, were minimal and short lived.

The Wildlife Service also studied the effects of both fenitrothion and phosphamidon on birds. This was done by taking pre- and post-spray bird counts during the operation in 1968. There appeared to be little toxic effect on most birds and no dead birds were found in the treated areas. However, a few birds were observed exhibiting signs of "intoxication" from the insecticide, i.e. loss of equilibrium, tremors, and inability to fly. Phosphamidon appeared to be more toxic than fenitrothion. No studies were conducted on the toxicity of insecticides on birds in Newfoundland in 1969. Investigations on the effect of fenitrothion on birds during the 1969 spruce budworm control operation in New Brunswick substantiated the earlier findings in Newfoundland. These results were presented at the meeting of the Interdepartmental Committee on Forest Spraying operations in 1968 and 1969 (Pearse 1968 and Pearce and Teeple 1969).

RECOMMENDATIONS

The 1969 spraying operation was planned and organized in a more systematic manner than in 1968 and consequently progressed more smoothly. The following recommendations should improve the efficiency of any future aerial spraying operations in Newfoundland:

(1) A permanent forest protection group should be formed, comprised of representatives of the limit holders and headed by the Provincial authority. This group should meet at least annually to review forest conditions, provide leadership, and be in a "state of readiness" to act when serious problems develop.

(2) All decisions should be made promptly, particularly those pertaining to control operations, to allow adequate time for planning.

(3) There is a need for considerably greater flexibility regarding finances and manpower to handle crises situations such as the current hemlock looper outbreak. This type of flexibility exists in the case of serious forest fires.

(4) There is a need for up to date and accurate forest type maps showing species composition, age of stands, and other related information. Such maps would increase the accuracy and efficiency of any control operation and reduce the cost of planning and decision making.

(5) There is a need for an operational map at control headquarters showing forested areas, their priorities for treatment and the location of pre-selected spray blocks. This map is essential for plotting of data as they are received from survey and spray crews. A map of 1:250,000 scale was excellent for the spray operation conducted in 1968 and 1969.

(6) There is a need for a better method of determining the amount and distribution of insecticide reaching the target area. The spray droplet cards currently in use are unsatisfactory. Cards which are not affected by rain, dew, etc. and which could be left in the forest for several days are needed.

(7) More spray aircraft of the range and carrying capacity of the DC-3 should be made available for future operations if

airfields are a long distance from areas to be sprayed. This is important, as was demonstrated by the recent hemlock looper outbreak in Newfoundland, where infestations were scattered and some a long distance from existing airfields.

(8) Sufficient aircraft should be available for spraying when required, to ensure that the operation is completed before serious defoliation occurs. Any resulting increase in costs would be offset by the increase in protection efficiency. Spraying of even moderately defoliated stands does not provide appreciable protection.

(9) Helicopters for larval surveys should be chartered for at least a two-month period and be available by the first week of June. This would ensure more effective pre- and post-spray sampling.

COSTS OF SPRAYING

Costs of the spraying operations have been reported by Holmes and Brennan (1968) and by Holmes (1970). In 1968, the total cost of spraying 431,000 acres was $408,445 or $0.95 per acre. In 1969, the total cost of spraying 2,054,900 acres was $1,447,000 or $0.70 per acre. In the first year costs were shared equally by the three limit holders, NFS, Bowaters, and Price, and in the second year equally by these agencies and the Federal Government. In addition to the above, the cost of all detection and appraisal surveys were borne by NFRC and amounted to $78,670 in 1968 and $97,778 in 1969. A breakdown of NFRC costs are shown in Appendix II.

APPRAISAL OF DAMAGE

Figures compiled over the past six years show that the hemlock looper defoliated an estimated 1,807,100 acres of balsam fir. Of this total 750,800 acres were severely damaged, and 246,600 acres, containing approximately 6,165,000* cords of pulpwood were killed. Industry has reported that, up to the fall of 1970, they have salvaged an estimated 170,000 acres of severely defoliated and dead stands. They have also indicated that they plan to salvage the accessible and most valuable of the remaining dead and damaged stands.

The annual progress of defoliation and stand damage is summarized in Table IV.

Table IV.- Extent and intensity of hemlock looper defoliation in acres

Year	Defoliation		
	Light and Moderate	Severe	Total
1966	300	-	300
1967	40,700	79,900	120,600
1968	338,400	228,900	567,300
1969	462,200	273,500	735,700
1970	188,100	135,300	323,400
1971	26,600	33,200	59,800
Totals	1,056,300	750,840	1,807,100

*Using a yield at 25 cords/acre.

in the progression of tree mortality in defoliated stands. Trees die more rapidly in some areas than in others even though the degree of defoliation may be lower. However, most of the mortality occurred in trees defoliated 75% or more, but 25% of the trees were killed in some stands only 50% defoliated. It appears that about 10% mortality will occur in trees that were about 30% defoliated (Hudak, Meades and Sutton, 1971). The physiological condition of the stand is an important factor influencing the progression of tree mortality. Stands under stress from previous attack by other pests or because of poor site conditions, or over-maturity, are less able to withstand defoliation. For example, stands damaged by balsam woolly aphid were killed after only 1 year of attack by relatively low population levels of the looper.

It is known that damaged trees are highly susceptible to infection by disease organisms. Infection by Armillaria mellea (Vahl ex Fr.) Kummer probably accounts for much of the mortality in the lower defoliation classes. It has also been shown by Singh and Carew (1971) that the incidence of A. mellea is influenced by soil pH and the range of 4 to 5 is most optimal for fungal growth. These relationships may help to explain why tree mortality will occur in lower defoliation classes on some sites and not on others.

Results of these studies also show that trees killed by the hemlock looper have an acceptable moisture content, wood density and amount of decay, for the production of ground wood pulp, for at least 4 years following mortality; trees are considered dead the year following complete defoliation. If these trees are infected with A. mellea, the rate of deterioration is increased, the moisture content and wood density is lower, and the amount of decay is larger than those not infected. (Hudak, Meades and Sutton, 1970).

FACTORS RESPONSIBLE FOR THE DECLINE OF THE OUTBREAK

Numerous factors have contributed to the decline of the current looper outbreak. Some of the most apparent of these include chemical spray operations, disease organisms, parasitism and predation, and age of the outbreak. Evidence to support the above conclusions are as follows:

(1) The chemical control operations conducted in 1968 and 1969 were successful. In treated areas the intensity of defoliation and tree mortality was reduced.

(2) The incidence and intensity of disease infection, notably by two entomogenous fungi of the genus *Entomophthora*, seems to have increased. From the results of surveys and sampling it appears that these fungi were responsible for the collapse of two localized infestations in 1969, and one in 1970. In 1971 the disease was widespread and undoubtedly caused the collapse of several infestations.

(3) The role of parasitism and predation has not been thoroughly studied. However, results of preliminary investigations indicate that neither one appreciably influences the pattern of an outbreak initially. Parasitism, particularly by tachinid flies, may have some effect on localized infestations as evidenced by the increasing rate of parasitism by this group, from 13% in 1969 to 17% in 1970 and 22% in 1971. Birds are the only regularly occurring vertebrate predators and 22 species have been found to prey on the looper, some exclusively on the later instars and pupae. They do not appear to have any appreciable effect on influencing the course of an outbreak.

(4) The history of previous looper outbreaks in Newfoundland indicates that they usually last from 5 to 7 years. This is the sixth year of the outbreak and all indications are that it is weakening rapidly as evidenced by the decrease in the areas of defoliation since 1969 (Figs. 15, 16, 17). With the exception of some areas of mature and overmature fir on the Baie Verte and Northern peninsulas, the majority of the susceptible fir stands on the Island have been heavily infested or defoliated for 2 years and no further defoliation should occur in these areas during the current outbreak.

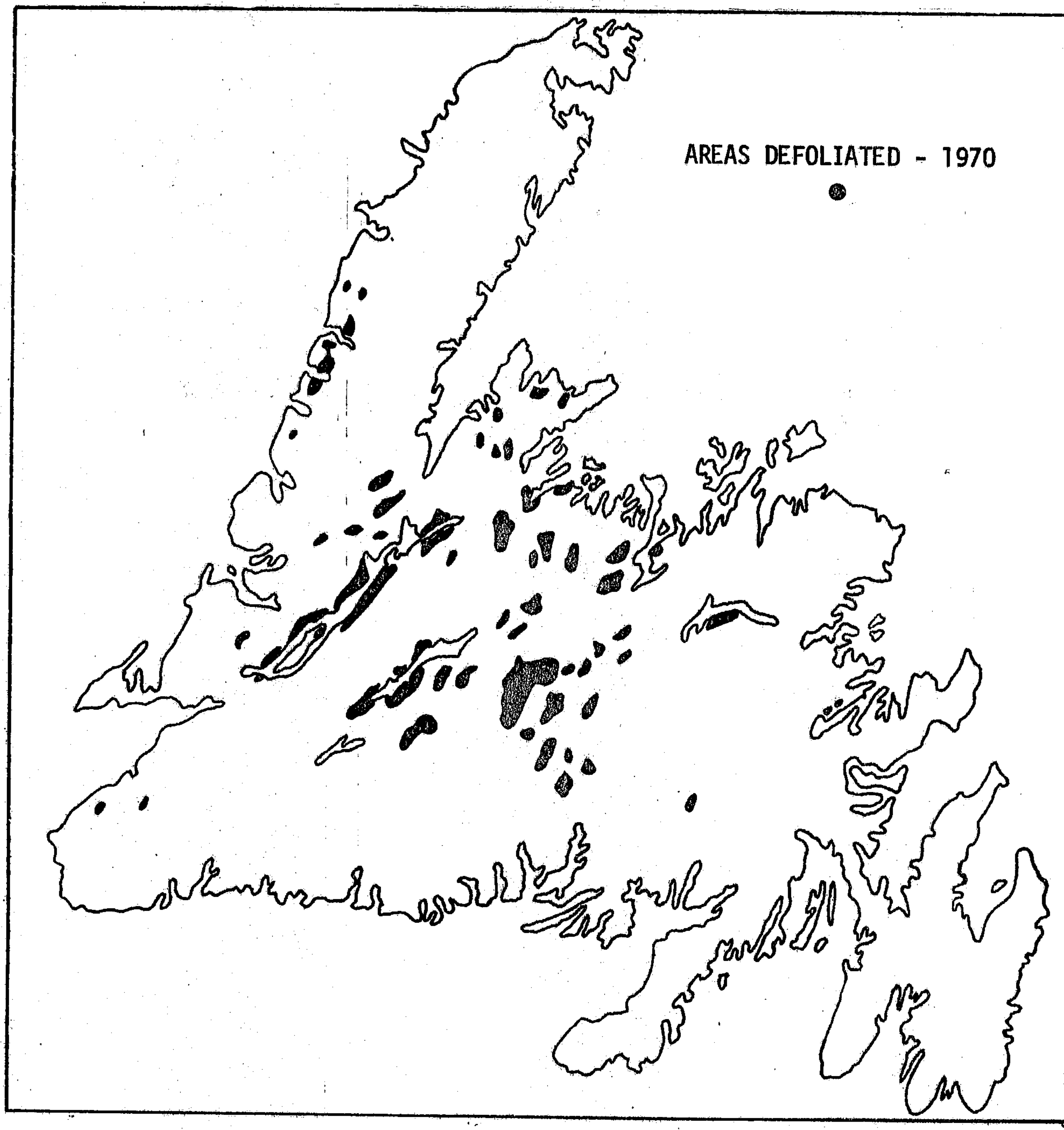

Fig. 16, Areas defoliated by the hemlock looper in 1970.

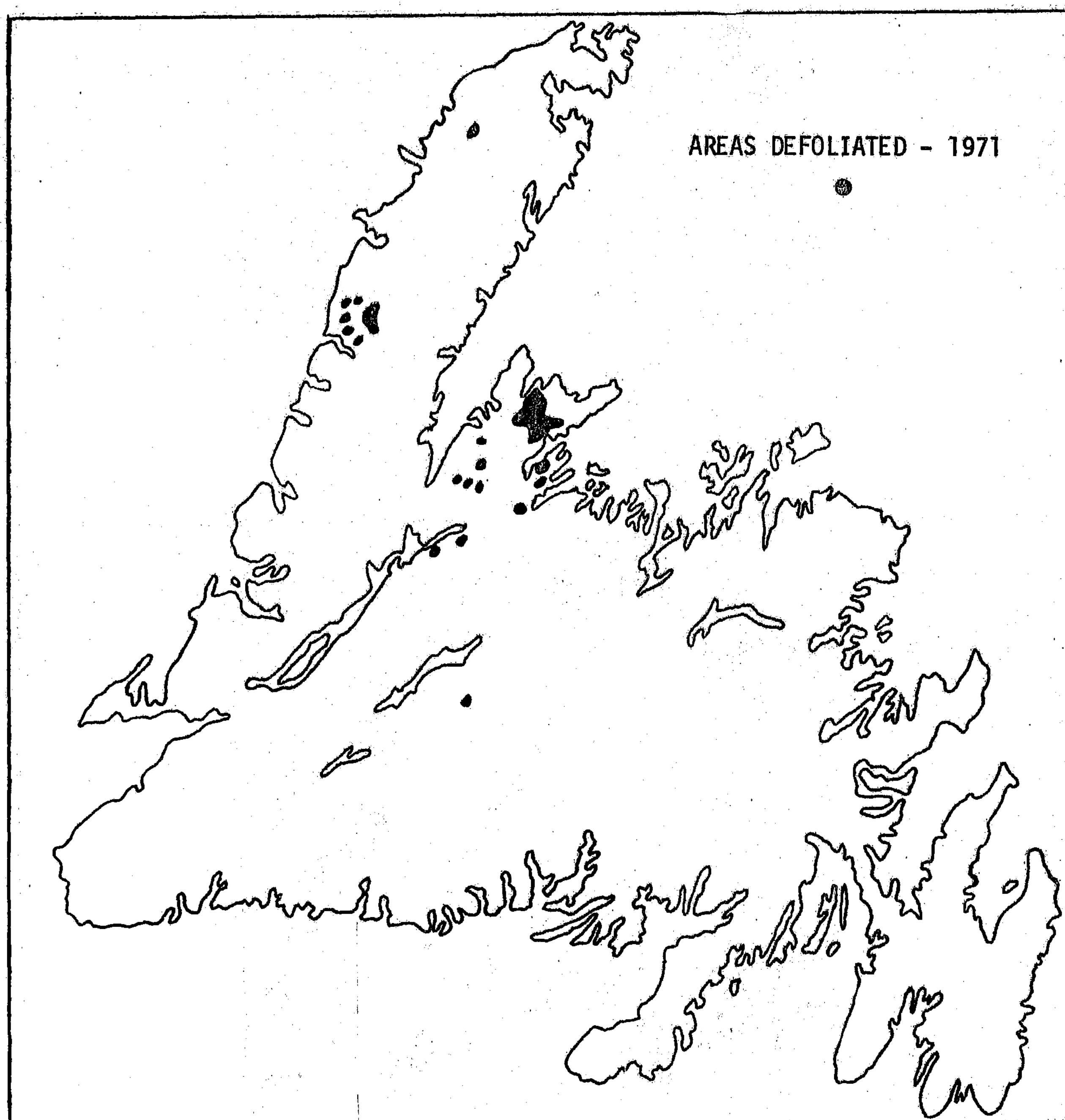

Fig. 17, Areas defoliated by the hemlock looper in 1971.

CONCLUSIONS

The history of the eastern hemlock looper in Newfoundland shows that outbreaks of this insect are cyclic, consequently forest agencies may periodically be confronted with providing emergency controls. The unprecedented rate of development of the current outbreak created the first critical situation of this kind in the Province requiring the aerial spraying of an estimated 2,500,000 acres of balsam fir forest. This operation was largely successful but was not accomplished without many problems. Therefore, this report has documented the more important experiences encountered and has recommended procedures that will minimize mistakes should the need to spray arise again.

The principal requirements recommended for protecting fir forests from excessive damage by the looper are re-emphasized in summary below:

(1) Ideally, forests should be maintained in a vigorous condition; balsam fir becomes most susceptible to mortality from looper attack when under stress e.g. overmaturity, or when previously damaged by other insects such as the balsam woolly aphid. Therefore, after consideration of economic principles, every effort should be made to delineate forest areas required to provide for the long-term requirements of the industry. Users should then develop and apply management-harvesting plans designed to significantly reduce the vulnerability of fir stands to severe looper damage.

(2) Salvage operations should be considered, as an alternative to aerial spraying, as a method for minimizing losses from looper attack. However before such a decision can be reached forest managers will have to consider several factors including age of the outbreak (outbreaks usually begin to weaken after 3 years), intensity and extent of damage in infested areas, accessibility and economic value of damaged stands and the capacity of industry to utilize the wood within the salvage period (about 5 years following mortality, in Newfoundland). Salvage operations should emphasize the highest priority for harvesting the most severely damaged stands especially if they have previously been weakened by other factors.

(3) If surveys indicate the need for an aerial spraying program several considerations are necessary to ensure an efficient operation and effective protection.

(a) A planning group, composed of representatives from the forest agencies, should be established immediately by the appropriate authorities. (Ideally, because of the serious nature of forest insect problems in Newfoundland, it is suggested that a permanent committee of this kind be established to appraise looper and other insect problems annually, recommend action, and plan and direct control operations as required.)

(b) The planning group or committee should be well-qualified and their recommendations given careful consideration by controlling authorities. Decisions on control action should be made promptly to ensure the timely approval of adequate funds required for optimum protection of selected stands. Early planning and funding is required to ensure that an adequate supply of insecticide and aircraft are available and to provide sufficient time to prepare appropriate sampling procedures for pre-spray evaluation of looper distribution and numbers.

(c) Stands should be treated during the year that populations increase to infestation levels and preferably from late June to mid-July, in Newfoundland, when larvae are most easily killed and before feeding causes critical damage.

The authors recognize that even though all of the above suggestions are followed they would be of little value without the continuous monitoring of the Island's balsam fir forests to predict looper conditions. This function is conducted annually by the Forest Insect and Disease Survey of the Canadian Forestry Service. Furthermore, it is also recognized that continued research is required to improve our knowledge and use of natural control factors such as parasites and disease. However, no immediate panacea can be expected from these studies, and natural control factors may never provide acceptable protection from this insect. Therefore, at least for the immediate future, aerial spraying with insecticides may be necessary to avoid disasterous losses of wood during periods of extensive outbreaks.

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APPENDIX I

Names and addresses of agencies referred to in this report.

Bowaters Newfoundland Limited (Bowaters)
Corner Brook, Nfld.

CIBA
AG. Basle, Switzerland

Cyanamid of Canada Limited
5550 Royalmount
Montreal, Que.

Department of the Environment - Federal
Fisheries Service*
Newfoundland Region
P.O. Box 5667
St. John's, Nfld.

Lands, Forests and Wildlife Service
Canadian Forestry Service*
Newfoundland Forest Research Center (NFRC)
P.O. Box 6028
St. John's, Nfld.

Environmental Research Institute* (CCRI)
Chemical Control Research Institute
25 Pickering Place
Ottawa 8, Ont.

Canadian Wildlife Service**
Eastern Region
P.O. Box 486
Fredericton, N.B.

Department of Mines, Agriculture and Resources - Provincial
Newfoundland Forest Service (NFS)
Bldg. 810, Pleasantville
St. John's, Nfld.

Newfoundland Wildlife Service
Bldg. 810, Pleasantville
St. John's, Nfld.

Forest Protection Limited (FPL)
P.O. Box 247
Campbellton, N.B.

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*formerly in the Department of Fisheries and Forestry.
**formerly in the Department of Indian Affairs and Northern Development.

Maritime Air Service Ltd.
McEwen's Field (R.R. No. 4)
Moncton, N.B.

Newfoundland Air Transport Limited
P.O. Box 3
Corner Brook, Nfld.

Price (Nfld.) Pulp and Paper Limited (Price)
Grand Falls, Nfld.

APPENDIX II

NFRC costs for planning, conducting and appraising the hemlock looper spray operations in 1968 and 1969.

	1968	1969
Salaries of continuing staff	$54,590	$57,091
Extra labor, accommodation and meals for survey crews	8,225	12,450
Vehicles*	3,000	600
Aircraft rental - fixed wing	3,835	2,275
helicopter	9,020	22,770
Aviation gas for helicopters**	-	2,592
Total costs	$78,670	$97,778

*Vehicle cost was based on 30,000 miles in 1968 and 6,000 miles in 1969.

**In 1968 aviation gas for helicopter was supplied by the contractor.