SPRUCE BUDWORM MATING DISRUPTION TRIALS USING SYNTHETIC ATTRACTANT IN CONREL FIBRES (ONTARIO, 1977)

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ABSTRACT

In 1977 in Ontario, synthetic sex attractant of the eastern spruce budworm (*Choristoneura fumiferana* [Clem.]) was applied by aircraft in Conrel fibres (hollow plastic fibrils, open at one end), to test its effectiveness in reducing population densities by disrupting mating. Two areas were treated, a 250 ha white spruce (*Picea glauca* [Moench] Voss) plantation with a population of 32 late instar budworm larvae per 45 cm branch tip (SEP), and two 10 ha plots with late instar larval populations < 1 per tip (BAM and BAP). Theoretical release rates of the attractant were in the order of 10 mg/ha/hr in SEP, 30 mg in BAM and 3 mg in BAP, but these were not checked in the field. In BAM and BAP, catches of male budworm in traps baited with virgin females were reduced by 99%, but no effect was discernible on the larval populations in the following generation; possibly the plots were too small, and ovipositing females moved in from outside. In SEC, catches of males in traps were also reduced by 99%, but further results were confounded by a collapse in the larval/pupal population and delays in application which resulted in some oviposition before application. However, there was no significant increase in the egg population in the treated plot following application, although the egg population doubled in the check plot. Further trials, though warranted, require accurate information on field release rates of the attractant, and on the movement of ovipositing female budworm. An application technique capable of applying the attractant more cheaply over larger areas than that used in these trials will be necessary before operational use of the attractant is possible.

RÉSUMÉ

En 1977 dans l'Ontario l'attractif sexuel synthétique de la Tordeuse des bourgeons de l'Épinette (*Choristoneura fumiferana* [Clem.]) a été épandu par voie aérienne dans des fibres Conrel (fibrilles plastiques creuses ouvertes à un bout), à l'effet d'en expérimenter l'efficacité à reduire les densités de population de cet insecte en perturbant son accouplement. Deux aires ont été ainsi traitées: une plantation de 250 ha d'Épinette blanche (*Picea glauca* [Moench] Voss) abritant une population de 32 larves de la Tordeuse au dernier stade par 45 cm d'extrémité de branche (SEP), et deux parcelles de 10 ha ayant des populations de larves du dernier stade < 1 par extrémité de branche (BAM et BAP). Les rythmes théoriques d'émission de l'attractif se situaient dans l'ordre de 10 mg/ha/h dans SEP, 30 mg dans BAM et 3 mg dans BAP, mais ils n'ont pas été vérifiés dans la nature. Dans BAM et BAP les prises de mâles de la Tordeuse dans les pièges appâtés avec des femelles vierges se trouvaient réduits de 20% sans effet décelable toutefois sur les populations larvaires dans la génération suivante; probablement, les parcelles étaient trop petites et les femelles ont dû s'y introduire pour pondre leurs oeufs. Dans SEC les prises de mâles se trouvaient également réduites de 99% dans les pièges, mais les résultats ultérieurs ont été compromis par une résorption de la population de nymphes et de larves ainsi que par les retards d'application qui ont donné lieu à une certaine ponte. Toutefois, après l'application dans la parcelle traitée, il n'y a pas eu d'augmentation significative de la population d'oeufs, laquelle a pourtant doublé dans la parcelle témoin. Quoique justifiée, la poursuite des expériences nécessite des informations plus précises sur les rythmes d'émission de l'attractif dans la nature et sur la migration des femelles pondeuses de la Tordeuse. Avant de pouvoir utiliser l'attractif sur une base opérationnelle, il faudra trouver une technique permettant de l'appliquer plus économiquement sur des aires plus étendues, que ne le permettait la technique employée dans les présentes expériences.

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Cover photo: Wing-mounted pod used by Conrel for application of hollow fibres.

INTRODUCTION

In 1975 the synthetic attractant (fulure) of the eastern spruce budworm (*Choristoneura fumiferana* [Clem.]) was applied aerially to a 12 ha white spruce (*Picea glauca* [Moench] Voss) plantation near Searchmont, 50 km northeast of Sault Ste. Marie, Ontario. The material was formulated by National Cash Register in gelatin-based microcapsules and was applied halfway through the adult flight period at a rate of 7.4 g/ha. The result was a dramatic reduction in the numbers of males captured in sticky traps baited with virgin females (Sanders 1976). This was interpreted as strong evidence that the ability of males to detect and to orient themselves to calling females was seriously disrupted by the presence of the fulure. It was assumed that, in consequence, large numbers of females would never mate, so that any eggs they did lay would be infertile, and populations would be reduced the following year. However, the design of the experiment precluded any evaluation of the effects of the treatment on subsequent population densities. Trials were therefore planned for 1977 which would permit the evaluation of the effects of mating disruption on subsequent population densities.

Chemical communication between female and male budworm must take place over greater distances at low population density than at high, and it is therefore generally assumed that disruption will be more effective at low density than at high. However, because of the current extensive outbreaks of spruce budworm across eastern Canada, there is considerable interest in determining the potential of disrupting moderate to high density populations. Such trials would also provide a valuable opportunity for observing the effects of the treatment on moth behavior, since at low density moths would be too scarce to allow observations. Trials were therefore planned for both low and moderate to high population densities.

The only extensive area of low density budworm is in northwestern Ontario; therefore, trials were planned for within this area. Considerable historical information is available for the area surrounding Black Sturgeon Lake, where population sampling is routinely carried out. This area would serve as a control at little additional expense.

Ideally, high density trials should be conducted in isolated stands remote from the danger of invasion by gravid females, but such stands are uncommon. However, a 250 ha white spruce plantation near Sault Ste. Marie offered many advantages. Populations of budworm in the vicinity were forecast to be much lower in 1977 than in 1976. In addition, the relative scarcity of balsam fir (*Abies balsamea* [L.] Mill.) and white spruce stands in the area, the presence of Lake Superior to the west, and the direction of the prevailing winds suggested that invasion was unlikely to be a serious problem. The amount of assessment required was reduced by virtue of the fact that there was only one host tree species, while a comparable 12 ha stand 1.5 km away was used as a check plot. Finally, observations had been made on moth activity in this stand from a scaffold in 1976 which would provide excellent background for further observations in 1977 following the application of the fulure.

Wind tunnel investigations on spruce budworm have suggested that a concentration of fulure between 5 and 10 nanograms/m^3 would be sufficient to disrupt spruce budworm male orientation to a calling female. This approximates a release rate in the forest of 15-30 mg/ha/hr. Taschenberg and Roelofs (1978) obtained satisfactory results with the red banded leaf roller at a release rate of 15 mg/ha/hr. In view of the greater tree height in the forest, a rate of 30 mg/ha/hr was decided upon. Since fulure is expensive, the effectiveness of a low application rate was also tested.

The flight period of spruce budworm moths spans a maximum period of 3 weeks in any one location. To provide some leeway with respect to the date of application it was specified that the release rate should last 5 weeks.

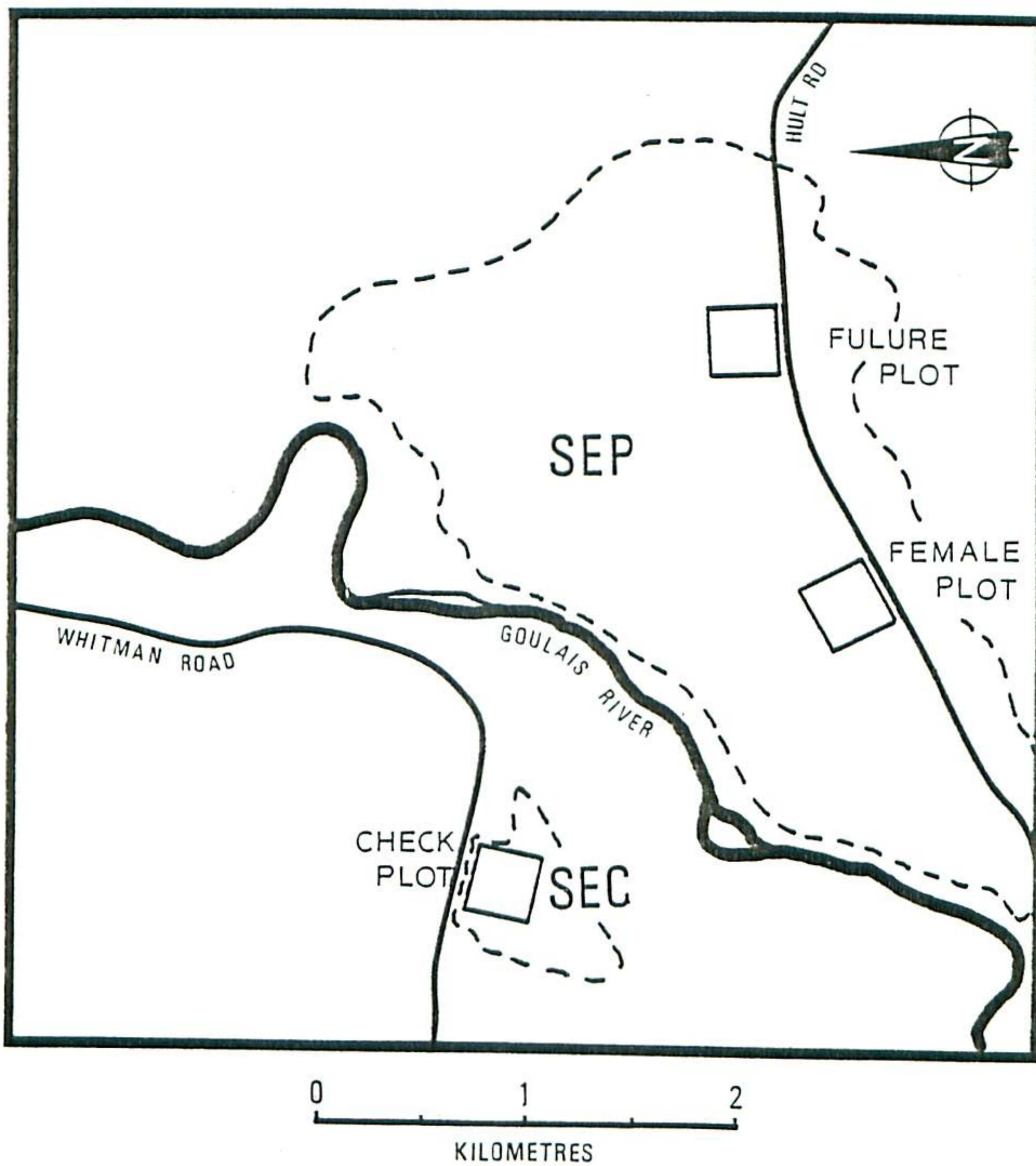
Conrel "chopped fibres" were chosen as the formulation for dispersing the fulure because the fibres are relatively large (> 1 cm long by 0.5 mm outside diameter), their application and subsequent detection are easy, and, according to researchers at the Conrel laboratories (Massachusetts) the release rate is almost constant under laboratory conditions.

PLOT LAYOUT

The trials were conducted in two locations: 1) near Searchmont (50 km N.E. of Sault Ste. Marie, Ont.) where budworm populations have been medium to high since 1973, and 2) near Black Sturgeon Lake (140 km N.E. of Thunder Bay, Ont.) where populations have remained low since the end of the last outbreak 20 years ago.

Searchmont

A 250 ha white spruce plantation (Plot SEP) located on a flat gravel terrace of the Goulais River was chosen for the treatment. A similar plantation of 12 ha (Plot SEC) about 1.5 km to the west on the other side of the river was chosen as a check plot (Fig. 1). This area was chosen to determine the effects of the pheromone on a high density budworm population. Ideally such a stand should be completely isolated to prevent possibility of re-invasion by gravid females from elsewhere. In this instance such conditions could not be guaranteed, but by treating all of the larger stand and leaving the smaller stand as the check plot, the danger of significant invasion from the check plot was minimized. Furthermore there are no extensive areas of host trees within 20 km of the plot, and populations of budworm in the forests surrounding the two plantations had shown considerable reductions in 1976.



SEARCHMONT

Fig. 1. Map of Searchmont area showing location of check plot (SEC) and treated plot (SEP), with location of the monitoring plots.

Both plots were planted between 1925 and 1928. In recent years defoliation was first noticed in 1973. By 1974 it was severe, and because the forecast was for continued high populations in 1975, plans were made to attempt control of budworm in SEP in 1975. Sampling during the third/fourth larval instars in 1975 gave population estimates of between 20 and 25 larvae per 45 cm branch tip in both plots. Fenitrothion was applied at a rate of 0.4 litres/ha on June 14. Application was too late to save much foliage and defoliation was subsequently estimated at 82%. (Defoliation was 98% in SEC.) (Howse et al. 1976)

Approximately halfway through the moth-flight period in 1975 microencapsulated fulure was applied to SEC at a rate of approximately 7.4 g fulure/ha (Sanders 1976). Application of fulure had a profound effect on catches of male moths in traps baited with virgin female budworms, but egg populations in the fall of 1975 were estimated at 222 egg masses/10 m^2 of foliage in SEP and 152/10 m^2 in SEC, and this indicated continuing high populations again in 1976. However, high populations did not materialize, and defoliation was only 6% in SEP and 23% in SEC in 1976. Nevertheless, egg counts of 360 egg masses/10 m^2 in SEP and 250/10 m^2 in SEC indicated further severe defoliation for 1977.

Black Sturgeon Lake

An area in which sampling has been carried out since 1960 was chosen as the check plot (BAA). Two other plots were selected from aerial photographs, which were of the same age and composition as BAA. These were designated BAM and BAP (Fig. 2). Observations in 1976 indicated that dispersal does not take place from low density populations, hence invasion by females from surrounding areas was not considered likely at Black Sturgeon Lake since the nearest area of moderate-to-severe defoliation was 150 km away. The main considerations affecting plot size were the flight of females in search of oviposition sites and dispersal of early instar larvae. Little is known of the distances ovipositing females might fly. However, 30 m per night would seem to be the maximum, and three nights of such flight would account for 85-90% of a female's egg complement. Hence a buffer zone of 100 m would appear necessary. The dispersal of small larvae is not likely to be of significance over distances greater than this. Plots measuring 300 m x 300 m were therefore chosen to provide a 100 m buffer zone and a central core of 100 m^2 in which the effects of the treatment could be assessed.

MATERIALS

Synthetic Attractant

The Δ-11-tetradecenal was synthesized by ChemSampCo, Columbus, Ohio. To ensure that the composition of the material was satisfactory,

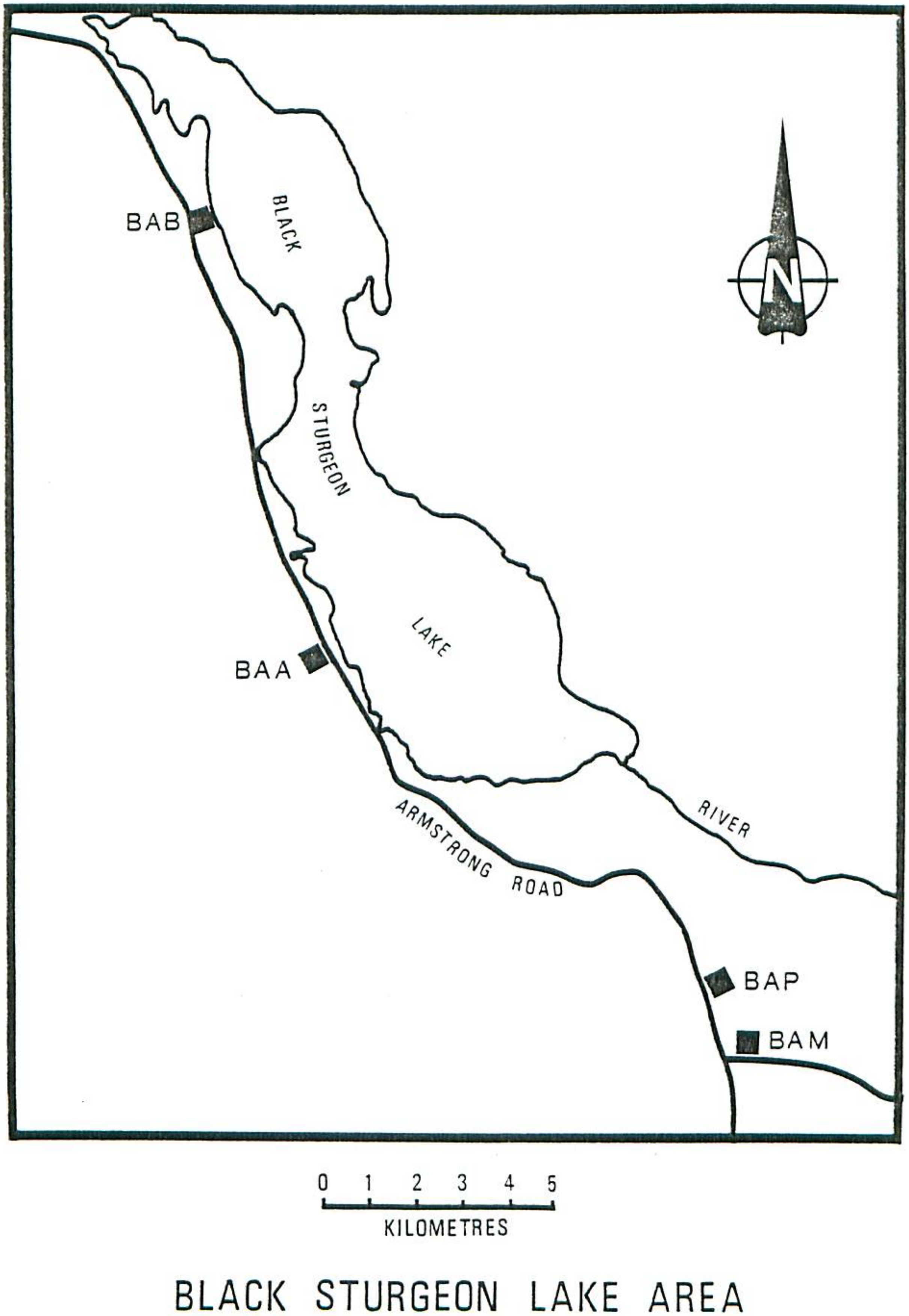


Fig. 2. Map of plot locations at Black Sturgeon Lake.

ChemSampCo supplied 1 g to Dr. I. Weatherston of the Forest Pest Management Institute in Sault Ste. Marie for analysis. Weatherston determined the composition to be as follows:

	%
trans-11-tetradecenal	84.57
cis-11-tetradecenal	6.99
major impurity (definitely not alcohol or acetate)	3.07
12 other compounds	5.37

The *trans*: *cis* ratio was therefore 92.37 : 7.63.

Approximately 17.9 kg of this material was shipped as 50% solution in hexane by ChemSampCo to the Conrel laboratory in Massachusetts on 24 May, 1977 for incorporation into Conrel hollow fibres.

Fibres

The Conrel hollow fibres used were approximately 15 mm long and 0.218 mm inside diameter, crimped at one end with the other end left open (single open-ended fibres). The fulure as 50% solution in hexane was loaded into the fibres by Conrel. The yield was approximately 180 kg. This was shipped by Conrel to the Great Lakes Forest Research Centre in 45 drums, each containing approximately 4 kg. The average weight of a fibre was 2.78 mg (360 fibres per g). As calculated in the Conrel laboratories (Massachusetts), the release rate of fulure from each fibre at 21°C was 5 μg/day or .208 μg/hr.

Sticker

The sticker used to hold the fibres onto the foliage and branches was a polybutene from Kingsley and Keith, Toronto. Polybutenes are used as lubricants in food processing machines, as they are inert, odorless and tasteless. They are obtainable in various viscosities, the heaviest, grade 1900, being the material used as an adhesive in many insect traps. The grade used in this operation was 300.

Application

<u>Theoretical application rates</u>: The theoretical application rate required was based on an average release rate of fulure of 30 mg/ha/hr. Preliminary data obtained by the Conrel laboratories in Massachusetts indicated that this would require 180,000 single open-ended fibres/ha. Subsequent data from Conrel gave a release rate per fibre of 0.208 μg/hr, which would have required only

145,000 fibres/ha for a release rate of 30 mg/ha/hr. However, the target at the time of application was 180,000 fibres/ha.

Actual application: Conrel (Arizona) provided the equipment for application, a wheeled Cessna 185 equipped with a custom designed pod under each wing. The pods contained two chambers, one filled with the fibres, one with the sticker. The two were mixed together shortly before emission when the coated fibres were distributed by a fan rotating at approximately 3200 rpm. This aircraft was calibrated to emit 6000 fibres/ha when flying at a height of 15 m.

Application of the fibres was not limited by weather conditions to the same extent as are aerial applications of conventional chemical insecticides. As individual fibres are relatively large and the sticker adheres to wet surfaces, drift is minimal. Application therefore was not limited by wind and rain except to the extent that the operation was halted by strong or gusty winds and by heavy rain which were a hazard to flying.

i) Searchmont

Applications were made as follows:

June 28	-	3	loads
29	-	0	(rain)
30	-	12	loads
July 1	-	6	loads
2	-	6	loads
3	-	0	(rain)
4	-	0	(BSL)
5	-	3	loads
Total	-	30	loads

Three loads were required to cover the entire 250 ha. There were therefore 10 complete applications over the whole plot. At an emission rate of 6000 fibres/ha, there would be a theoretical coverage of 60,000 fibres/ha.

ii) Black Sturgeon Lake

Plot BAM (receiving the higher deposit) was sprayed during the evening of July 4 and the morning of July 5. Plot BAP was sprayed on the morning of July 5.

The theoretical deposit on these two plots (determined by the number of passes made by the plane and the theoretical emission rate) was 180,000 fibres per ha for BAM and 18,000 per ha for BAP. The theoretical deposit in BAM was lower than that originally planned.

This was due to time constraints; additional material applied to BAM would have entailed a third sortie by the spray-plane, which, for a ferry distance of 150 km each way, would possibly have meant a delay of one more day in an operation that had already been going on for 8 days.

Deposit Assessment

<u>Searchmont</u>: Approximately 44,000 g of loaded fibres were released over the 250 ha Searchmont plot. If 1 g contains 360 filled fibres, there will be a deposit of 63,500 fibres/ha which corresponds well with the theoretical figure above of 60,000/ha.

i) Deposit Screens

Actual deposit was recorded on screens measuring 71 cm x 71 cm (500 cm^2). The screens were constructed of 5 x 2.5 cm wooden frames with black cambric fabric stretched over them. The screens were suspended by string from 5 x 2.5 cm wooden crosspieces erected in the tree canopy, one half to two thirds up the crowns of dominant or codominant trees. The screens were positioned so that they had a clear exposure to the sky with no overhanging branches. Before the application of the fibres the screens were positioned horizontally. After the application they were lowered for examination. The original plan was to reposition them vertically and to examine them weekly to determine how many fibres remained (to evaluate the effectiveness of the sticker) and to remove the fibres from a sample of the screens to compare the length of the liquid columns at successive examinations and assess the release rate of the fulure. However, this plan was abandoned when it was found that the numbers of fibres on the screens were too low for such an analysis, and that the sticker was absorbed by the cambric fabric allowing the fibres to fall off easily.

The screens were therefore left horizontal throughout and three counts were made, the first on July 6 after the final application, the second on July 18, the third on July 25 when the screens were removed. The numbers of fibres are shown in Table 1. On the day following the final application fibres were found on 17 of the 30 screens, with a total of 57 fibres. With an area of 500 cm^2 per screen, this gives an estimated deposit of 32,500/ha.

ii) Plastic Drop Sheet

Deposit was also measured by covering part of a disused side road in the treated area with black plastic. The plastic covered an area of 61.5 m^2 and was placed out on June 28 prior to the application of the first load. A count was made on July 2 after 24 loads (four fifths of the total) had been applied. Following the count the plastic was turned over and left until July 6 when another count was made. On July 2, 112 fibres were recorded, on July 6 a further 90, for a total of 202 on 61.5 m^2, for an estimated total deposit of 34,000 fibres/ha.

Table 1. Number of Conrel fibres found on cloth screens in the treated plot (SEP) at Searchmont on July 6, 1977 following the final application made on July 5, and at two subsequent inspections.

	Female plot[a]			Fulure plot[a]		
Screen Number	July 6	July 18	July 25	July 6	July 18	July 25
1	2	0	0	0	0	0
3	0	0	0	0	0	0
5	4	0	0	2	0	0
6	0	0	0	0	0	0
8	1	0	0	0	0	0
10	3	2	0	2	6[b]	0
11	5	2	1	2	2	0
13	2	0	0	1	0	0
15	1	1	0	1	1	1
16	3	2	1	7	8[b]	8
18	0	0	0	0	0	0
20	2	1	1	1	0	0
21	2	0	0	1	0	0
23	0	0	0	1	1	0
25	8	1	0	3	0	0
26	0	2	0	1	0	0
28	0	0	0	2	0	0
30	0	0	0	-	-	-
Total	33	11	3	24	18	9

[a] For plot locations see Figure 1.

[b] Increased counts may be due to error in the first count, but could also be due to fibres falling onto screens from surrounding trees.

The distribution of the cluster size of the total of 259 fibres found on plastic and screens at Searchmont is shown in Table 2. The optimum distribution of the sources of release of the synthetic attractant to effect disruption of male orientation is not known. In these experiments the objective was to achieve uniform permeation of the atmosphere. For this purpose the greater the number of point sources, and the more uniform their distribution, the better. In the event, only 25% of the fibres were deposited as single fibres, while 29% were in clusters of 10 or more. Therefore, some means of obtaining a better distribution of the fibres should be considered.

Table 2. Frequency distribution of cluster size of Conrel fibres immediately following application, Searchmont SEP plot.

Number of fibres per cluster	Number of clusters			Total number of fibres
	Plastic	Screens	Total	
1	36	28	64	64
2	9	5	14	28
3	5	2	7	21
4	5	2	7	28
5	2	1	3	15
6	1	0	1	6
7	2	0	2	14
8	1	0	1	8
9	0	0	0	0
10	2	0	2	20
11	2	0	2	22
12	0	0	0	0
13	0	0	0	0
14	1	0	1	14
19	1	0	1	19
Total				259

The estimates of 32,500 and 34,000 fibres/ha are gratifyingly similar. However, they represent only slightly more than half of the theoretical quantity emitted. The reasons for this discrepancy are not known. The average weight of one fibre (with no allowance made for the sticker) is 2.78 mg. Therefore the fibres would not be subject to much drift. It is possible, however, that a considerable number of fibres were deposited outside the plots as a result of overshoot and delays in switching off the spray equipment when passing over the plot boundaries. It is also possible that the trees produced a 'shadow' effect and prevented many fibres from reaching the deposit trays and the plastic sheet.

Black Sturgeon Lake: Ten deposit screens were deployed in both BAM and BAP. Following the application on July 4 and 5 counts in BAM were as follows:

6 screens had 0 fibres
2 screens had 1 fibre each
1 screen had 9 fibres (in 1 clump)
1 screen had 15 fibres (in 1 clump)

The deposit on the 10 screens (each measuring 500 cm^2) was therefore 26, for an estimated total of 52,000/ha. Statistically this is a poor sample, but it suggests that deposit was lower than intended (180,000/ha).

No fibres were recorded on any of the screens in BAP; therefore, no estimate of the deposit can be made.

Release Rate of Pheromone

The release rate of Δ-11-tetradecenal from the fibres was estimated by Conrel (Massachusetts) to be 0.208 μg/fibre/hr at 21°C. Therefore, to provide a release rate of 30 mg/ha/hr, about 145,000 fibres would be required. The material emitted at Searchmont was estimated at 63,500 fibres/ha, which corresponds to a release rate of 13.2 mg/ha/hr. The two estimates of deposit would provide release rates of 6.8 mg/ha/hr for the deposit screens and 7.1 mg/ha/hr for the plastic drop sheet. The estimate of 52,000 fibres/ha on plot BAM at Black Sturgeon Lake corresponds to a release rate of 10.8 mg/ha/hr.

At the intended deposit of 180,000 fibres/ha, the deposit on each 500 cm^2 deposit-screen would have averaged nine fibres/screen. The original intention was to collect the screens at intervals, to measure the length of the liquid column in each fibre, and to calculate from the averages the actual rate of release in the field. This proved impossible because of the low number of fibres on the screens and the wide variability in the amount of fluid in the fibres. Instead, fibres were dipped in sticker and placed on glass slides, 10 per slide. The length of fluid in each fibre, with an allowance for air bubbles, was then measured, and the slides were placed out on July 14 on the scaffold in SEP, five slides (50 fibres) at 12 m and five (50 fibres) at 2 m. One slide from each level was collected on July 19 for remeasurement. Both slides still contained 10 fibres each, but the results of the remeasurement were anomalous, many of the fibres having more liquid inside than at the first measurement. The remaining slides were therefore collected for remeasurement on July 26, at which time 29 of the 40 fibres were still in place at the 12 m level, 38 out of 40 at the 2 m level. The remeasurements gave anomalies similar to the earlier ones.

This has tentatively been attributed to the fact that the sticker and attractant are intersoluble and the probability that on a smooth, non-absorbent surface such as a glass slide, a pool of sticker remains in contact with the fibre. This could result in prolonged contact between the sticker and the attractant in the fibres, with sticker flowing into the fibres and possibly attractant flowing out. Actual release rates of the attractant in the field are therefore not known.

Adhesion of Fibres in the Field

The loss of fibres from the horizontal deposit screens is shown in Table 1. On July 6, the day after the last application, there were 57; 12 days later, on July 18, there were only 29 (50%), and 19 days later, only 12 (21%). However, because of the problems outlined under Deposit Assessment at Searchmont, this was not a satisfactory method of assessing adhesion on the trees.

To simulate field conditions, fibres were dipped in sticker and were placed out individually by hand at various heights and on various parts of the tree and recounted at various intervals. The results are shown in Table 3. All of the fibres placed on needles in the upper crown of the trees remained in place over the 12 days of observation: 76% remained on bark and lichen of living branches in the upper crown, but only 20% remained on bark and lichen on dead lower branches, although 90% remained on the exposed wood of dead lower branches. The polybutene sticker used appears to be effective, therefore, for holding the fibres in the tree canopy for at least 12 days. However, on any absorptive surface such as dead, loose bark it is less effective. Possibly, therefore, it would be less effective in stands which have been heavily defoliated for a nomber of years.

Weather

Deviations of the mean daily temperatures from normal and records of precipitation are given in Figure 3. The data for Sault Ste. Marie were obtained from the Monthly Summary of Local Climatological Data issued for the Sault Ste. Marie, Michigan National Weather Service Office of the National Oceanic and Atmospheric Administration. The Thunder Bay data were obtained from the Atmospheric Environment Service of the Department of the Environment, Thunder Bay Airport.

Clearly, the early part of June was abnormally cool. The timing of the spray application, June 28 to July 5, coincided with a very wet and generally cool period. However, the period following the application saw fairly normal temperatures and a moderate amount of rain.

Table 3. The adhesion of Conrel fibres to foliage and branches of white spruce in plot SEP, Searchmont.

Location	Height (m)	Numbers of fibres on dates shown		
		14 July[a]	19 July	26 July
Needles	12	25	25	25
Bark/lichen of living branches	12	25	24	19
Bark/lichen of dead branches	2	10	5	2
Exposed wood of dead branches	2	10	10	9

[a] Day fibres placed out.

ASSESSMENT

Sticky Traps

For monitoring the effects of the treatments, traps baited with sex pheromone were deployed in a 5 x 5 grid configuration in each plot with 20 m between traps. In addition to the 25 baited traps, five unbaited traps were set in another line on the end of the grid, making the layout a 5 x 6 grid, as illustrated in Figure 4. At Searchmont, in plot SEP, two such grids were laid out, one in which the traps were baited with virgin females (female plot), and the other in which traps were baited with fulure (fulure plot) (Fig. 1). Because of the shape of the check plot (SEC) the grid was modified so as to have 25 female baited traps, five unbaited checks and 10 fulure-baited traps. In BAA, BAM and BAP the grid layout was as illustrated in Figure 4, 25 traps being baited with virgin females, and five being unbaited checks. In all plots Pherocon 1CP traps were hung at a height of 2 m on a dead branch away from living foliage. Fulure was incorporated into solid, low temperature-fusing polyvinyl chloride as described by Daterman (1974) and Sanders and Weatherston (1976) (after Fitzgerald et al. 1973). The PVC was formed into cylindrical pellets, 10 mm long and 4 mm in diameter, containing 3% fulure by weight (approximately 3.5 mg). The pellets were fastened with insect pins inside the traps, at the top.

Virgin females were housed in small screen cages, 2.5 cm long and 2.5 cm in diameter, which were taped to the top inside the traps.

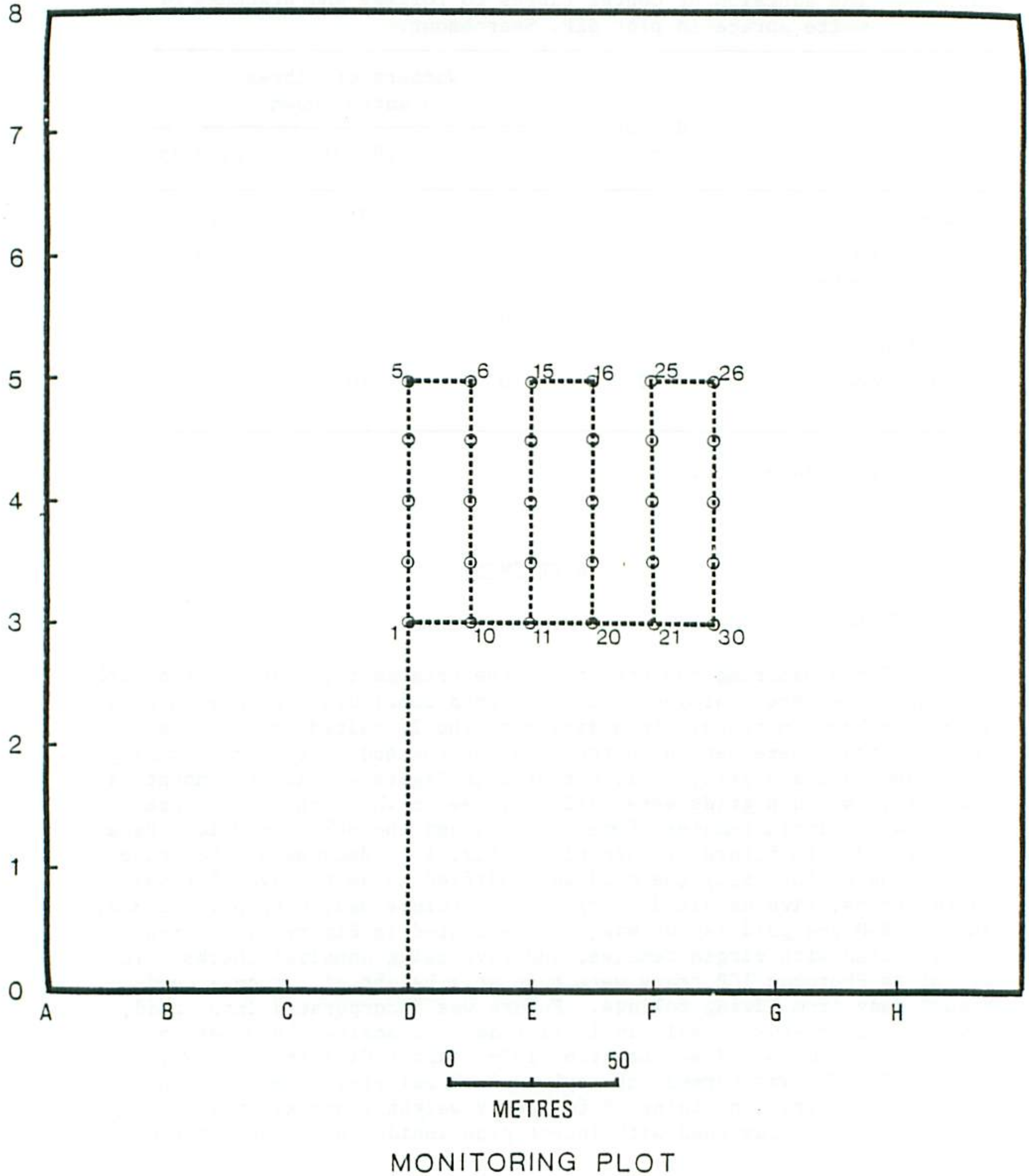


Fig. 3. Layout of monitoring plot.

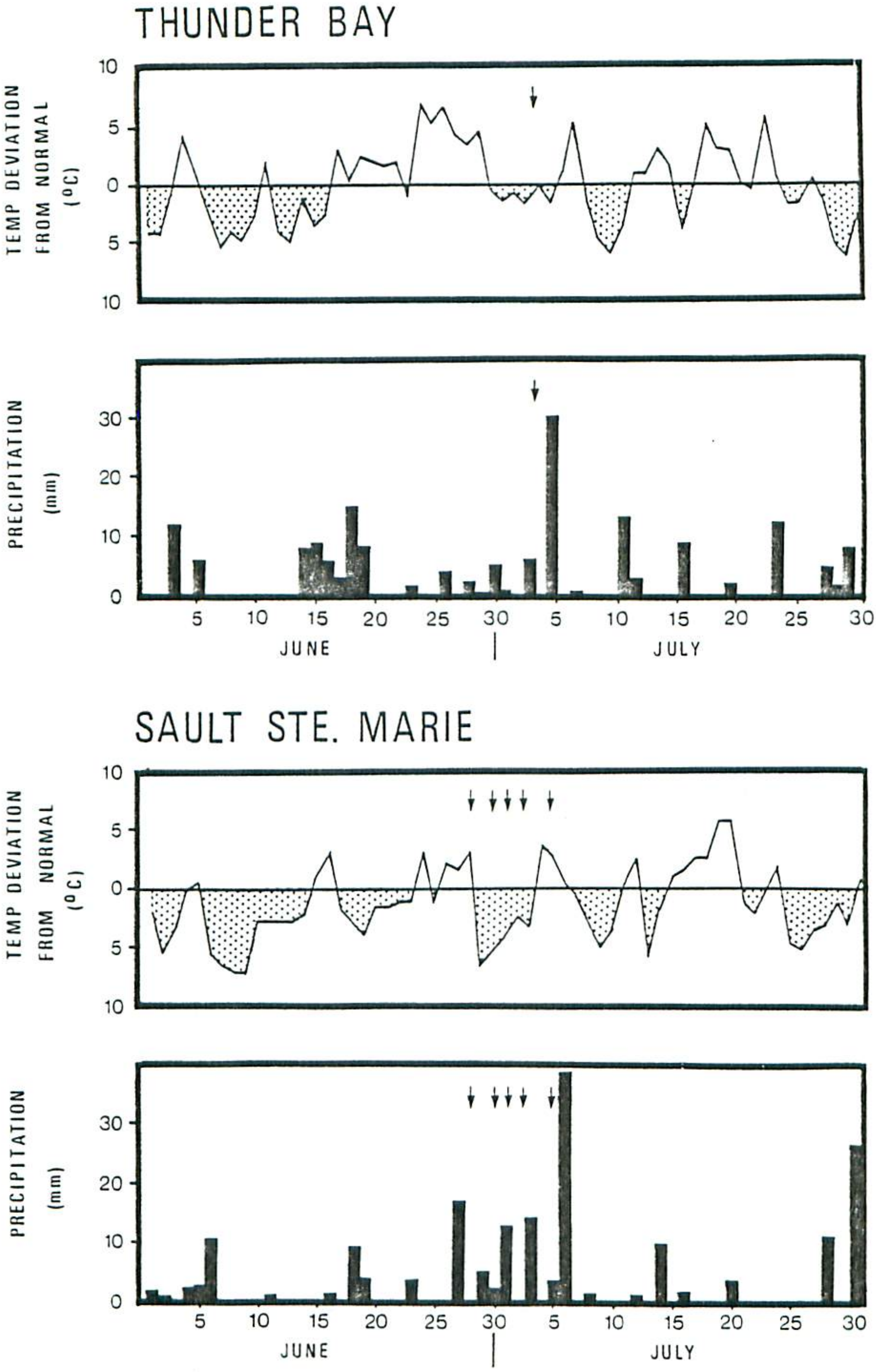


Fig. 4. Deviations of mean daily temperatures from normal, and daily precipitation recorded at Sault Ste. Marie, Mich., and Thunder Bay, Ont. for the months of June and July, 1977. Arrows indicate dates of fulure application.

Females were 1 day old when first deployed in the field, and were replaced when 5 days old (i.e., every 4 days). Since the attractiveness of females is influenced by their age, deployment of the females was staggered, traps being deployed in the even-numbered locations 2 days after they were deployed in the odd-numbered locations so that all subsequent changes in the even-numbered locations occurred 2 days after those in the odd-numbered locations.

All traps were checked daily. The sticky trap-bottoms (liners) were replaced when the catch exceeded 10 males, but all liners were changed every 4 days, regardless of the catch.

Live Traps

Live traps were made from cardboard ice cream cartons (1 qt, or approx. 1.1 ℓ) in size. An aluminum-screen cone was inserted in each end with a central opening approx. 1.5 cm in diameter. A single 1-day-old virgin female budworm was placed inside the trap which was then hung on a dead branch at a height of 2 m. Each morning the traps were checked. Records were kept of whether the female had escaped, had been preyed upon (usually by spiders), or was in copula with a male, or whether a male was present. If a male was present the female was preserved in alcohol and later dissected to determine if she contained a spermatophore (an indication of successful mating). Fresh females were placed in the traps when a male was present, when a female had escaped or been preyed upon, or when a female was 5 days old (when the old female was removed).

Ten such traps were deployed in SEP and SEC, and 10 each in BAM and BAA.

Sampling

Population estimates were obtained by collecting branches from the mid-crown of dominant and codominant trees in each plot. The samples were then transferred to the laboratory and examined in a foliage examination centre at the Great Lakes Forest Research Centre. For sampling of large larvae, pupae and eggs, 45 cm branch tips were taken; for overwintering second-instar larvae whole branches were taken.

All branch samples were taken from within the monitoring areas shown in Figures 1 and 2. The sampling crew proceeded up line #1, down line #3 and up line #5, collecting one third of the required number of samples from an area 20 m on either side of each line. In SEC, where there were two monitoring areas, half of the sample was taken from each monitoring area, resulting in one sixth of the total from along each line. Sample trees were chosen subjectively. No attempt was made to sample the same trees at successive sampling times.

In the check plot and treated plot at Searchmont, pretreatment larval sampling was carried out on May 26 to determine the initial population densities in the plots. This was followed by a pupal sample on June 30 to obtain an estimate of the adult population. Because of the delays in application of the attractant a sample was taken on June 30 to determine how many eggs had been laid prior to application of the treatment. Egg samples were again taken on July 27 following moth flight. A sample of whole branches was taken on August 18 to estimate the number of second instar larvae in hibernacula by 'washing' the sample branches in NaOH (Miller and McDougall 1968). A further sample was taken in October for an estimate of second instar larval populations by 'forcing'.

At BSL, pretreatment larval populations were sampled on May 31, pupae on July 6 and 7. No egg samples were taken at BSL because of the low populations (too many branches would have been required to obtain a precise population estimate); however, samples were taken by washing on August 23 and 24 for estimates of the second instar population. A further sample was taken in October by forcing.

The number of samples taken from each plot at each stage of budworm development is shown under RESULTS. Sample size was determined from data in the literature to provide a population estimate with a standard error of 15% of the mean.

PHENOLOGY

The phenological development of the spruce budworm population at Searchmont, based on samples of 50 insects, is shown in Figure 5. The latter half of May was extremely warm, and consequently development was well advanced in early June. However, June was a cool month (Fig. 4) with temperatures well below normal, especially in the first 2 weeks. Consequently, insect development slowed down, as shown in Figure 5, and for a period of at least 10 days (June 12 to 22) few additional insects pupated. This slowdown in development rate prompted the delay in application of the attractant from June 20 to June 27 and provided additional time for aircraft trials and calibration in Arizona. The first emerged male pupae were found on June 28, but the first males were caught in fulure-baited traps on June 21, when three traps caught one, one, and two males, respectively. After June 28 emergence was evidently very rapid and no unemerged pupae were found after July 5, although, because of a crash in budworm populations, pupae were very hard to find. It is therefore probable that the attractant was applied during the period when female budworm were emerging, the first application (June 28) coinciding with the first emergence, the last (July 5) coinciding with final emergence. Few, if any, females would have emerged before some attractant had been applied; however, many would have emerged when the concentration was still very low.

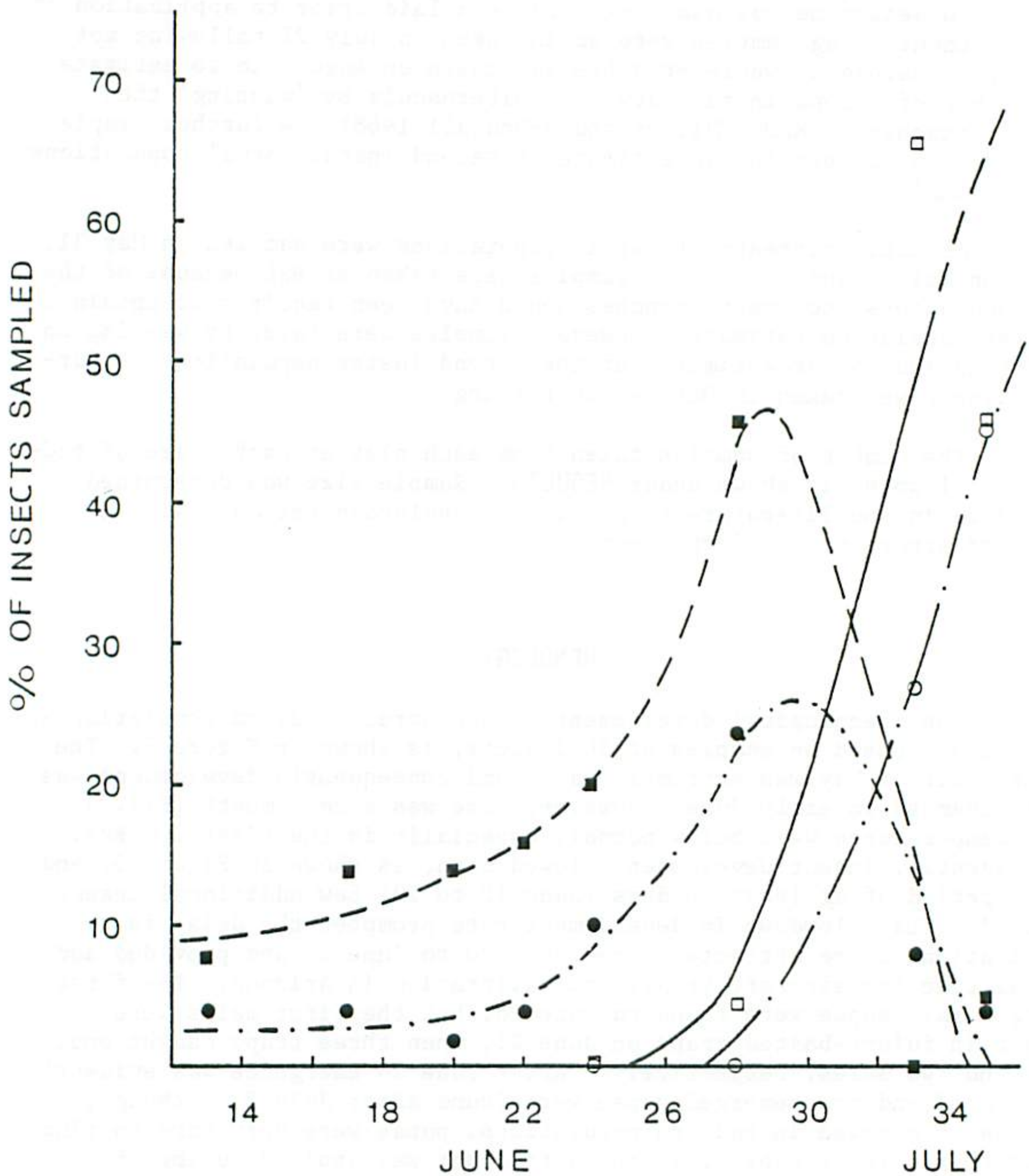


Fig. 5. Phenological development of spruce budworm populations at Searchmont on white spruce, 1977. Solid circles (females) and squares (males) denote unemerged, healthy pupae; open circles (females) and squares (males) emerged pupae. The points represent the percent in each category based on a total of 50 insects examined on each sampling day.

No phenological checks were made at Black Sturgeon. However, the first traps, baited with virgin female budworm, were placed out on July 1, and they caught males the same night.

RESULTS

Sticky Traps

The average daily catches of male spruce budworm are shown in Table 4 for Searchmont, Table 5 for Black Sturgeon Lake and graphically in Figures 6 and 7. The percent reduction in catch was calculated from the catches in check and treated plots after 50% of the fibres had been applied, i.e., on June 30 at Searchmont and on July 5 at Black Sturgeon Lake. Catches in the female-baited traps at Searchmont following application were reduced by 99.4%, compared with 97.3% in the fulure-baited traps. At Black Sturgeon Lake the reduction in catches in the female-baited traps following application was 98.8% in both the treated plots.

Live Traps

At Searchmont, 10 live traps were deployed in each plot for 11 nights. This represents 110 opportunities for mating. At Black Sturgeon Lake, 10 live traps were deployed in BAA and BAM for 13 nights. However, because of a shortage of fresh female insects, some of the traps remained empty on some nights. The number of opportunities for mating were 112 in the check plot BAA and 125 in BAM. No live traps were placed in BAP. Results are shown in Table 6. Of the 110 opportunities in the Searchmont check plot (SEC) males were found with 35 females, 25 of which contained a spermatophore. Of the remainder, 31 escaped from the traps. In the treated plot (SEP), out of 110 opportunities, males were found with only two females, neither of which contained a spermatophore; 30 females escaped. In the BSL check plot (BAA), out of 112 opportunities, males were with 13 females, only four of which contained spermatophore; 24 females escaped. In the plot treated with the higher amount of attractant (BAM), out of 125 opportunities, a male was found with a female only once and that female contained no spermatophore; 37 females escaped.

Sampling

Pretreatment larval sampling: Results are shown in Tables 7 and 8. At Searchmont on May 26, populations per 45 cm branch tip were 31.8 in the check plot and 32.3 in the treatment plot, a non-significant difference. The larvae were held at 5°C after collection on May 26, and examined on June 6. At that time there were no third instars; the average instar was 5.0 in both the check and the treatment plots, the pupae being designated as instar VII.

At Black Sturgeon Lake populations were far lower, averaging 0.59 per 45 cm tip on white spruce and 0.26 on balsam fir. The distribution of larvae per branch is shown in Table 9. On June 14, after storage of larvae at 5°C for 2 weeks, the average instars at Black Sturgeon Lake were 5.5 on white spruce and 5.0 on balsam fir. This confirmed previous observations that development is faster in Ontario on white spruce than fir.

Table 4. Average daily sticky-trap catch at Searchmont in check plot (SEC) and treated plot (SEP). Totals refer to catches made after 50% of spray had been applied (July 1 onward).

	SEC			SEP			
	Fulure	♀♀	Check[a]	Fulure[a]	Check[a]	♀♀[a]	Check[a]
n	10	25	5	25	5	24	5
June 27	-	-	-	27.0	0	16.0	0
28	-	13.3 ± 3.4	0	20.5	0	7.0	0
29	0	12.6 ± 2.5	0	0.72	0	0.12	0
30	-	2.9 ± 1.0	0	0.08	0	0	0
July 1	3.0 ± .60	0.8 ± 0.3	0	0.60	0	0	0
2	2.7 ± .68	0.04±	0	.04	0	0	0
3	6.4 ± 1.6	2.5 ± 0.7	.4	.04	0	0	0
4	13.7 ± 2.1	3.9 ± 0.9	0	.20	0	0	0
5	40.6 ± 4.8	20.8 ± 3.3	0	.32	0.2	.04	0
6	48.9 ± 4.2	3.9 ± 0.8	.4	.56	0	.16	0
7	50.2 ± 1.9	27.9 ± 4.0	.2	2.2	0	.24	0
8	56.6 ± 3.4	34.7 ± 3.7	0	2.9	0	.08	0
9	70.9 ± 3.2	39.8 ± 3.8	.2	2.6	0	0	0
10	54.4 ± 5.4	27.9 ± 4.3	.2	2.5	0	.12	0
11	66.5 ± 2.2	43.0 ± 3.2	.4	3.2	0	.36	0
12	73.2 ± 2.5	36.0 ± 3.9	0	1.7	0	.16	0
13	·54.5 ± 3.7	36.4 ± 3.9	.2	1.2	0.2	.60	0
14	58.0 ± 3.8	34.0 ± 8.3	0	1.6	0	.20	0
15	41.6 ± 2.3	12.1 ± 2.6	0	0.32	0	.08	0
16	81.9 ± 3.4	27.8 ± 4.2	0	0.56	0	0	0
17	29.7 ± 2.3	10.9 ± 2.5	0	0.84	0	0	0
18	37.6 ± 4.8	11.5 ± 2.5	.2	0.28	0	0	0
19	17.4 ± 1.9	7.6 ± 2.0	0	0.16	0	.04	0
20	12.0 ± 1.0	2.1 ± 0.7	0	0.12	0	0	0
21	9.2 ± 1.0	3.4 ± 1.2	0	0.20	0	0	0
22	7.9 ± 1.4	2.2 ± 0.5	0	0.16	0	0	0
25	15.9 ± 1.9	5.2 ± 0.9	0	0.32	0	0.12	0
27	0.6 ± 0.6		0	0.16	0	0	0
Aug. 4	1.2 ± 1.2	1.8 ± 0.5	0	0.08	0	0	0
Total July 1<	854.6	396.2		22.9		2.2	
% Reduction				97.3		99.4	

[a] Numbers too low to warrant calculation of standard errors.

Table 5. Daily catches per sticky trap at Black Sturgeon Lake in check plot (BAA), in plot treated with approximately 180,000 fibres per ha (BAM) and in plot treated with one-tenth of this amount (BAP). Totals refer to catches after application of attractant. (July 6 onward).

	BAA		BAM		BAP	
	♀♀	Check[a]	♀♀	Check[a]	♀♀	Check[a]
July 3	1.39 ± 0.57	0	.08	0	5.92 ± 1.40	0
4)			4.24	0	6.68 ± 1.77	0
5)	7.80 ± 1.79	0	0.32	0	0.32 ± 0.14	0
July 6	2.40 ± 0.61	0.2	0.52	0[a]	.0	0
7	1.32 ± 0.39	0	0	0	0	0
8	5.48 ± 1.27	0	.08	0	.04	0
9	4.36 ± 1.01	0	0	0	.04	0
10	2.20 ± 0.63	0	.08	0	.08	0
11	7.12 ± 1.55	0	0	0	.04	0
12	1.80 ± 0.43	0	0	0	.04	0
13	7.84 ± 1.20	0	.12	0	.04	0
14	9.08 ± 1.55	0	0	0	.04	0
15	9.36 ± 1.70	0	0	0	.12	0
16	5.00 ± 1.02	0	.04	0	.16	0
17	3.32 ± 0.64	0	.04	0	.12	0
18	1.88 ± 0.47	0	0	0	0	0
19	4.56 ± 1.23	0	0	0	0	0
20	2.56 ± 0.68	0	0	0	.04	0
21	1.72 ± 0.43	0	0	0	.08	0
22	1.16 ± 0.43	0	0	0	.04	0
Totals July 6 <	71.16		0.88		0.88	
% Reduction			98.76		98.76	

[a] Numbers too low to warrant calculation of standard errors.

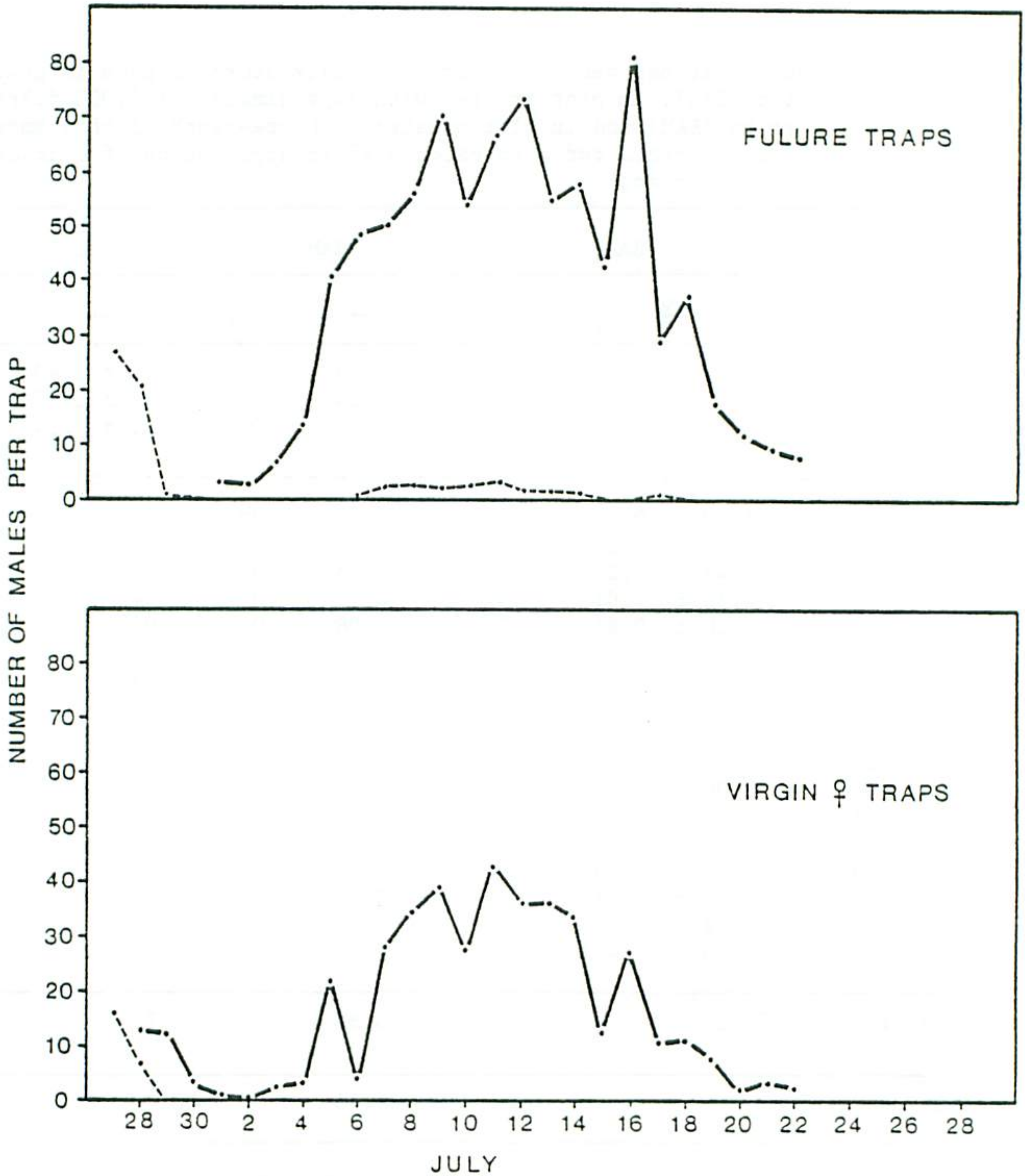


Fig. 6. Average daily catch per trap of male budworm in check plot (solid line) and plot treated with synthetic sex attractant (dashed line), Sault Ste. Marie, 1977.

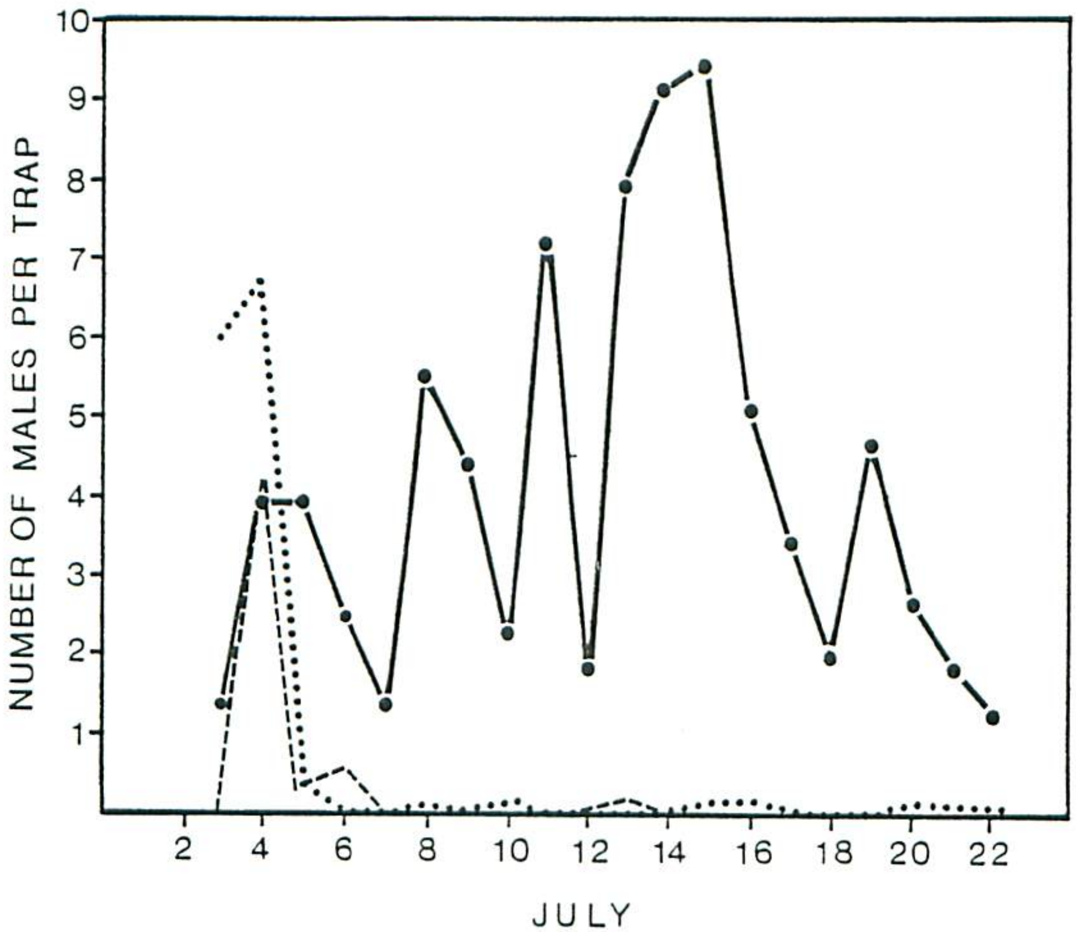


Fig. 7. Average daily catch per trap of male spruce budworm in check plot (solid line) and plots treated with synthetic sex attractant, (BAM broken line, BAP dotted line). Black Sturgeon Lake, 1977.

Table 6. The results of exposing virgin female budworm in non-sticky live traps. One female exposed for one night equals one opportunity for mating. Data are expressed as percentages of total opportunities.

Condition of female	Searchmont Treated (SEP)	Searchmont Check (SEC)	Black Sturgeon Lake Treated (BAP)	Black Sturgeon Lake Check (BAA)
Alone	67	35	57	53
Disappeared	27	28	30	23
Preyed upon	4	5	12	12
With male (but no spermatophore)	2	9	1	8
With male (containing spermatophore)	0	23	0	4
Total opportunities	110	110	125	112

Table 7. Pretreatment larval populations per 45 cm branch tip in check (SEC) and treated (SEP) white spruce plantations, Searchmont, 1977.

	Date of collection	Number of branches	Larval development (%) instars III	IV	V	VI	Larval counts $\bar{x} \pm 1SE$	$\frac{SE}{\bar{x}}$ %
SEC	26 May	25	0	42	19	39	31.8 ± 2.4	7.5
SEP	26 May	25	0	26	44	30	32.3 ± 3.0	9.3

Table 8. Pretreatment larval populations per 45 cm branch tip in check (BAA) and treated plots at Black Sturgeon Lake. Foliage kept at 5°C between collection date (May 31, 1977) and date of examination (June 14, 1977).

		Number of branches	Larval development (%) on 14 June				Larval counts	
			IV	V	VI	P	$\bar{x} \pm 1SE$	$\frac{SE}{\bar{x}}$ %
BAA	wS	200		-			0.530 ± .063	11.9
	bF	200		-			0.155 ± .038	24.5
BAM	wS	200	11	31	55	3	0.500 ± .061	12.2
	bF	200	39	39	22	0	0.170 ± .029	17.0
BAP	wS	200	12	32	55	1	0.730 ± .074	10.1
	bF	200	23	49	28	0	0.470 ± .058	12.3

Table 9. Distribution of budworm larvae on 45 cm branch tips collected from Black Sturgeon Lake, June 1, 1977.

Number of budworm (larvae/branch tip)	BAA		BAM		BAP	
	wS	bF	wS	bF	wS	bF
0	132	175	134	169	109	136
1	41	20	44	28	57	43
2	20	4	13	3	21	14
3	4	1	7	0	8	6
4	2	0	1	0	3	0
5	1	0	1	0	1	1
6	0	0	0	0	1	0
Total	200	200	200	200	200	200

Pretreatment pupal sampling: Results are shown in Table 10. In view of the very low counts in all plots no statistical treatment of the data has been attempted. The low populations at Black Sturgeon Lake were not unexpected: they represent a population reduction of approximately 98% from fifth instar to pupae--a reduction similar to that recorded the previous year at Black Sturgeon Lake, and one that may be normal in these relatively low populations. The low pupal populations at Searchmont were not expected, however; they represent a reduction of about 99.8% in both areas. This may well have been due to predation by a carabid beetle, the details of which will be reported elsewhere. This reduction did mean, however, that densities were far lower than anticipated, and this precluded observations on adult behavior, including female dispersal.

Table 10. Pupal populations per 45 cm branch tip, Searchmont and Black Sturgeon Lake, 1977

Area	Host	Date of collection	Number of branches	Total number of spruce budworm	$\bar{x}$/branch
SEC	wS	30 June	25	1	.04
SEP	wS	30 June	50	4	.08
BAA	wS	6 July	200	1	.005
	bF	6 July	200	2	.01
BAM	wS	7 July	200	2	.01
	bF	7 July	200	0	0
BAP	wS	7 July	200	4	.02
	bF	7 July	200	0	0

Egg sampling: Egg sampling was not carried out at Black Sturgeon Lake, since calculations revealed that the number of samples required for a precise population estimate would have been prohibitive.

At Searchmont, two samples were taken, one on June 30 when it was realized that oviposition was taking place before the completed application of the attractant, and one on July 27 after completion of moth flight. The results are given in Table 11. During the application of the attractant egg populations were significantly higher in the plot being treated than in the check plot. There is no apparent reason for this. Larval sampling indicated that phenological development was similar in the two plots. Pupal sampling did suggest a higher population in the treated plot, but the difference was not enough to be significant. Following treatment, egg populations almost doubled in the check plot--a significant increase. However, in the treated plot there was no significant increase following treatment. The evidence therefore indicates that, following treatment, no further eggs were laid in the treated plot.

Table 11. Egg population estimates at Searchmont on June 30, during application of attractant, and on July 27, after completion of moth flight. Counts are per 45 cm branch tip.

	n	SEC (check)	n	SEP (treated)
During treatment	25	0.36 ± .13	50	1.16 ± .35
During moth flight	75	0.71 ± .11	100	0.96 ± .12

Students t, null hypothesis

SEC during vs SEC after t = 1.74 *(p = .05)

SEP during vs SEP after t = 0.82 N.S.

Neither the size of egg masses nor the incidence of fertility was evaluated. Laboratory observations indicate that unmated females are delayed several days in the start of oviposition, and their egg masses are small and irregular (Outram 1971). Furthermore, since the examination of the branches for the egg masses was carried out after hatching of the eggs was complete, infertility would have shown up as unhatched egg masses. Those conducting the foliage examination were aware of the possibility of abnormalities but none were noticed.

<u>Post-treatment second instar larval sampling</u>: Estimates of the numbers of overwintering second instar larvae per 10 m^2 of foliage, taken from whole branch samples obtained late in August and October, are shown in Tables 12 and 13.

At Searchmont the data are in conflict with the estimates of egg populations. Egg sampling indicated no difference in final egg populations between the two plots SEC and SEP. However, the estimates of overwintering larval populations suggest a population in SEC one and a half times as high as that in SEP, the treated plot. Reasons for this discrepancy are not apparent. However, the possibility that some of the eggs in SEP were infertile should not be ignored, and future trials should ensure that the assessment will detect this infertility.

Table 12. Estimates (for Searchmont) of populations of overwintering second instar larvae per 10 m^2 of foliage obtained by washing whole branches in warm NaOH.

Plot	Host	Date of collection	Number of branches		Number of second instar larvae/10 m^2
SEC	wS	18 Aug	20		45.1
	wS	3 Oct	20		32.0
	wS	31 Oct	20		40.0
		Total	60	Average	39.0
SEP	wS	18 Aug	20		10.2
	wS	3 Oct	20		32.0
	wS	31 Oct	20		36.0
		Total	60	Average	26.1

Table 13. Estimates (for Searchmont and Black Sturgeon Lake) of overwintering populations of second instar larvae per 10 m^2 of foliage obtained by washing whole branches in warm NaOH.

Plot	Host	Date of collection	Number of branches	Number of second instar larvae/10 m^2
BAA	wS	23 Aug	100	3.4 ± 0.05
	bF	23 Aug	96	2.4 ± 0.04
BAM	wS	24 Aug	97	3.7 ± 0.08
	bF	24 Aug	100	4.8 ± 0.10
BAP	wS	24 Aug	100	2.8 ± 0.06
	bF	24 Aug	100	3.3 ± 0.05

No significant differences were detectable among the plots at Black Sturgeon Lake. There is therefore no evidence that the treatments had any effect on the post-treatment population, in spite of the pronounced reduction in the catches of male budworm in traps in both treated plots.

Attempts were made to corroborate these data by "forcing" overwintering larvae from branches collected in March, 1978. However, the number of insects collected was unaccountably low, and this raises questions about the suitability of the technique for assessing larval densities at low population densities. Consequently, the data are not considered here.

COMMENTS

1. The objectives of the operation were:

   A. To determine if permeating the atmosphere with Δ-11-tetradecenal (fulure) (approximately 95% E: 5% Z) throughout the flight period of the eastern spruce budworm would reduce population densities of the budworm in the following generation.

   B. To determine if the effects of fulure differed between moderate and low population densities.

   C. To determine the effects of two different release rates of the fulure.

2. Populations in the moderate density plots (Searchmont) averaged 32 insects per 45 cm branch tip during the fifth instar, but crashed prior to the application of the fulure to fewer than 0.1 insects per 45 cm tip during the pupal stage. Populations in the low density plots (BSL) ranged between 0.15 and 0.73 per 45 cm branch tip during the fifth instar, but declined to approximately 0.01 during the pupal stage.

3. Permeation of the fulure was achieved by the aerial distribution of Conrel hollow fibres filled with fulure and coated in a polybutene sticker. Because of a delay in the start of the operation, inclement weather, minor breakdowns in equipment, and the small capacity of the spray equipment, application of the fulure was late in all areas. Sampling showed that as much as 50% of total oviposition had occurred in the moderate density plots (Searchmont) before application was terminated. No similar sampling was carried out in the low density populations (BSL) but it is probable that oviposition had begun there too before application was complete.

4. On the basis of data obtained in Conrel's Massachusetts laboratories, where fibres free of the sticker were used, the planned application rate was intended to give a release rate of approximately 30 mg fulure/ha/hr in the moderate density plot (Searchmont) and in one of the low density plots, and one-tenth of this in the other low density plot.

Because of delays in application the planned deposit was not achieved at Searchmont, where the actual deposit recorded corresponded to a theoretical rate of 6 mg/ha/hr. Although the planned number of fibres was emitted at BSL, the available measure of deposit suggests that the deposit was low.

5. Attempts to measure the release rate of the fulure from the fibres by placing them on glass slides in the field were unsuccessful. In many instances fibres gained liquid instead of losing it, possibly because sticker from the pool surrounding the fibres on the glass slide flowed into the fibres. In future, release rates must be determined by simulating field conditions as closely as possible, and placing fibres coated with sticker on the foliage.

6. In the moderate density populations (Searchmont) there was no significant increase in the number of eggs laid in the treated plot following treatment, but there was a significant increase in the check plot. The answer to the question "Does fulure reduce subsequent egg populations?" is therefore yes.

   In the low density populations (BSL) no egg sampling was carried out but the fulure did not reduce subsequent overwintering larval populations.

7. At both Searchmont and BSL the treatments resulted in a marked reduction in catches of male spruce budworm in traps baited with virgin female budworm, and in traps baited with the more potent synthetic fulure.

8. At both Searchmont and BSL the treatments resulted in a reduction in the number of males caught alive in live 'lobster pot' traps baited with untethered virgin females, and a reduction in the number of such females inseminated.

9. The reduction in the number of males caught in sticky traps baited with virgin females was similar in the two plots in the low density populations (BSL) treated with different densities of fibres.

10. There are three possible reasons for the failure of the treatment to show an effect on the subsequent generations in the low density populations (BSL):

    a) The treatment was ineffective. (This is unlikely in view of the dramatic reduction in trap catches and the positive effect in the moderate density population.)

    b) Eggs were laid before the treatment became effective. (Males were definitely flying before treatment; nothing is known of female activity, but the fact that catches of males continued for another 15 days suggests that emergence was not very well advanced.)

c) The plots were too small and partially gravid females moved into the sampling area in the centre of the plot during normal activity associated with oviposition. (This is possible; a buffer zone of 100 m was left to allow for this. Nothing is known of the distance moved by females engaged in oviposition, but 100 m may have been too little.)

11. The equipment used by Conrel for this trial is not suitable for application of the fibres at the rates prescribed, or on areas as large as those used. Carrying capacity is too small, application rate is too low. Further trials using Conrel material must await equipment more appropriate to forest use.

12. The deposit screens used for assessing deposit in this trial worked well in principle. However, the number of fibres collected was too small. In future trials the size of the screens should be increased to 1 m^2 and more screens should be used in each plot.

13. Although the estimates of the overwintering larval populations are consistent with the final estimates of the numbers of egg masses, it is possible that egg mass size and/or egg fertility are affected by the attractant.

CONCLUSIONS

1. The application of the fulure caused a profound reduction in the number of male budworm attracted to traps in both moderate and low density populations.

2. Application of the fulure caused a significant reduction in the number of eggs laid in the moderate density population.

3. No reduction of larval densities as a result of treatment could be demonstrated in either moderate or low density populations. Confounding factors were partial oviposition before treatment, and in the low density populations, small plot size.

4. Information is required on the distances travelled by females during oviposition (i.e., exclusive of long-range dispersal) to allow determination of minimum plot size. Plots of 10 ha are probably too small.

5. Release rates of the fulure *in the field* must be known for the full interpretation of any trial of this nature. Fulure trials should not proceed until adequate techniques for monitoring release rates are devised.

6. Provision must be made to assess accurately the number and distribution of fibres following application.

7. To apply the fibres on the scale required in forestry a more efficient method involving fewer 'lifts' is necessary.

8. In addition to determining the effects of the treatment on trap catches, on incidence of mating and on subsequent egg and larval populations, provision must also be made for assessing the number of infertile eggs.

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