Use of the Multi-Pher® trap to monitor spruce budworm populations

Luc Jobin, Charles Coulombe, and Michèle Bernier-Cardou

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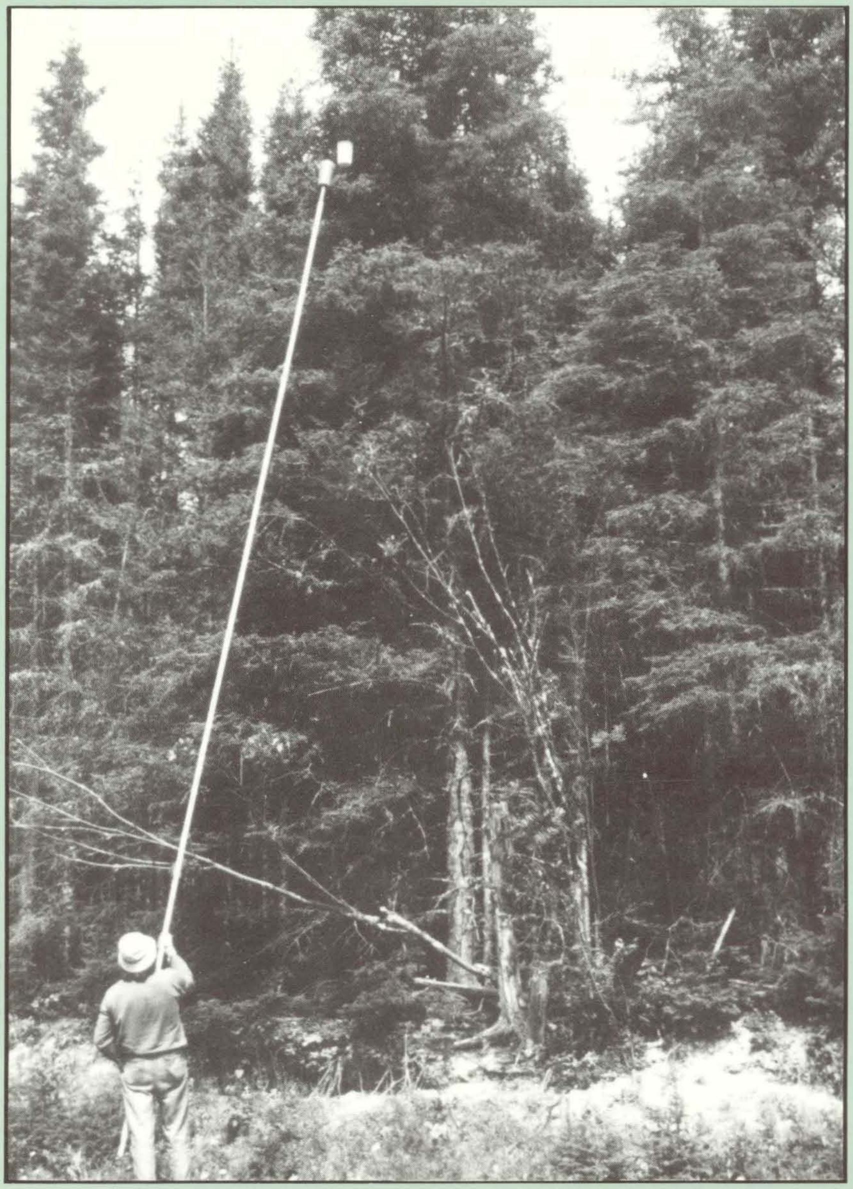

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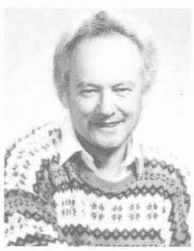
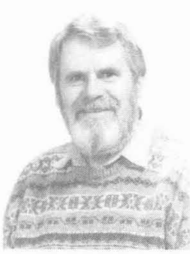


Luc Jobin, Ph. D.

Over the past ten years, Luc Jobin has been working on developing insect traps and new methods of detecting and monitoring harmful forest insects. These methods are also used to study the forest entomological fauna in forest ecosystems. One of the traps developed is used for detecting and monitoring the spruce budworm and the hemlock looper. Luc Jobin obtained a Ph.D. in science from Université Laval in 1968 and joined LFC in 1972 after working for 11 years in the field of agricultural entomology.



Charles Coulombe

Charles Coulombe has been a forest technician at LFC since 1967. He first worked on remote sensing and then switched to entomology, specializing in the study of the hemlock looper and the gypsy moth. He has been working in this field with Luc Jobin since 1972 and since 1982 he has contributed to the development of pheromone traps (Multi-Pher®) and light traps (Luminoc®). During the summer, most of this work is carried out at the research station at Métis-sur-Mer, Quebec.

Michèle Bernier-Cardou

Michèle Bernier-Cardou has been the senior statistician at the Laurentian Forestry Centre since 1989. She earned an M. Sc. from the University of Edinburgh in 1975. From 1975 to 1988, she was the regional statistician at the research branch of Agriculture Canada in Sainte-Foy, Quebec.

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ABSTRACT

The Multi-Pher® insect trap was first manufactured and marketed in 1984. The following year, the Multi-Pher® trap was used in the development of a detection and monitoring system for spruce budworm (SBW) (*Choristoneura fumiferana* Clem.) over a major part of the distribution area of this species in North America. Between 1984 and 1989, twelve experiments to assess and optimize trap effectiveness were conducted in balsam fir (*Abies balsamea* [L.] Mill.) stands infested by spruce budworm in the Gaspé Peninsula. The number of male SBW moths captured was considered an adequate measure of trap effectiveness. Three models of the Multi-Pher® trap were compared. Several elements of the trap were tested: the lure brand and holder, insecticide, funnel, baffle, color and trap placement, its cleanliness and holder.

The Multi-Pher®-1 model proved to be the most effective. White Multi-Pher®-1 traps placed high in the crown of balsam fir trees and fitted with a funnel, baffle, Biolure® bait, and 1/8 of a Vapona™ strip were more effective than their respective controls placed about 1.5 m from the ground. Neither lure holder nor insecticide dose seemed to affect the number of males captured. In one experiment designed to verify the effectiveness of the insecticide, the average number of males was four times higher in the insecticide-lined traps than in the control traps, but this difference is not significant because the experiment was conducted at only two sites and the difference between average catches in the insecticide-lined and control traps was not stable. Vaportape II™ was less effective than 1/8 of a Vapona™ strip. The average number of males in traps hanging from 45-cm wooden sticks nailed to tree trunks was comparable to the number captured in the controls hanging from dry branches, but was lower when the rod was 70 cm rather than 45 cm long.

Appendix 1 lists Lepidoptera species other than the SBW caught in the Multi-Pher® traps from the Quebec SBW monitoring system.

RÉSUMÉ

Le piège entomologique Multi-Pher® a été manufacturé et mis en marché en 1984. L'année suivante, il devint le principal outil d'un vaste réseau de détection et de surveillance de la tordeuse des bourgeons de l'épinette (TBE) (*Choristoneura fumiferana* Clem.) couvrant une importante partie de l'aire de distribution nord-américaine de ce défoliateur. Entre 1984 et 1989, 12 expériences ont été menées dans des peuplements de sapin baumier (*Abies balsamea* [L.] Mill.) de la péninsule gaspésienne, pour évaluer l'efficacité de ce nouveau piège et pour optimiser sa configuration et son mode d'utilisation. Le nombre de captures de papillons mâles de la TBE a été considéré comme une mesure d'efficacité adéquate dans toutes les expériences. On a comparé les trois modèles du piège Multi-Pher®. Plusieurs éléments du piège et de son mode d'utilisation ont été essayés: l'appât sexuel et son support, l'insecticide, l'entonnoir, le déflecteur de vol, la couleur et la position du piège dans l'arbre, sa propreté et le support du piège.

Le modèle Multi-Pher®-1 du piège à phéromone s'est avéré le plus efficace parmi les trois modèles comparés. Les pièges Multi-Pher®-1 blancs suspendus dans la cime de sapins baumiers et munis d'un entonnoir, d'un déflecteur de vol, de Biolure® et de 1/8 de plaquette Vapona™ étaient plus efficaces que les pièges témoins respectifs. Ni le support de l'attractif sexuel, ni la propreté du piège ne semble avoir affecté le nombre moyen de captures. Lors d'une expérience qui avait pour but de vérifier si la présence d'un insecticide augmentait le nombre de captures, ce nombre moyen était quatre fois plus élevé dans les pièges qui contenaient un insecticide que dans les pièges témoins, mais cette différence n'était pas significative, probablement parce que l'expérience n'a pas été faite que dans deux sites, et la différence entre les captures moyennes des pièges contenant de l'insecticide et celles des pièges-témoins n'était pas la même dans les deux sites. Le Vaportape II™ était moins efficace que 1/8 de plaquette Vapona™. Il n'y avait pas de différence entre les captures moyennes des pièges suspendus à des supports de 45 cm et celles des pièges fixés à des branches. Par ailleurs les captures étaient moins nombreuses dans les pièges attachés à des supports artificiels de 70 cm.

Nous présentons en annexe une liste d'autres espèces de l'ordre des lépidoptères capturées accidentellement dans les pièges du réseau québécois de détection et de surveillance de la tordeuse des bourgeons de l'épinette.

INTRODUCTION

The development of systems or networks for monitoring populations of insects harmful to forests and agriculture is often based on the use of traps baited with a synthetic sex attractant. The insects caught may serve a number of purposes, including the study of their annual cycle, and variations in populations of monitored species in view of developing efficient monitoring and control strategies.

A number of authors, including Sanders (1978), Houseweart et al. (1981), Kendall et al. (1982), Ramaswamy and Cardé (1982), Allen and Abrahamson (1983), Sanders (1984), and Allen et al. (1986a, b) tested various types of sex attractant traps to catch male moths of spruce budworm (SBW), *Choristoneura fumiferana* (Clem.), for the detection and measurement of changes in the population of this major defoliator of coniferous forests in northeastern America; these traps are not yet in commercial production. Non-saturating traps developed for other species of insects such as gypsy moth, *Lymantria dispar* L., do not meet the effectiveness and durability requirements of an SBW monitoring network (Allen et al. 1986a).

The Multi-Pher® trap (Figure 1), developed by the Laurentian Forestry Centre (Jobin 1986, Jobin and Coulombe 1988), has been used in Quebec since 1984 (For. Conserv. 1985) for monitoring spruce budworm and since 1985 in a North American network covering the entire distribution area of this major defoliator (For. Conserv. 1985, Allen et al. 1986b). The development and potential of the Multi-Pher® trap has already been discussed (For. Conserv. 1985), as well as a detailed description of the various parts, models available, and uses of the trap in forest and agricultural entomology (Jobin and Coulombe 1988). The technique for establishing a SBW monitoring network using the Multi-Pher®-1 trap was described by Allen et al. (1986b).

The various tests described in this report deal with the use of the Multi-Pher® trap and its effectiveness in catching male SBW moths, and is intended to answer the many technical questions that users may have. The tests were carried out from 1985 to 1989 in balsam fir stands in the Gaspé Peninsula to compare the effectiveness of three models of the Multi-Pher® trap, and to determine the best combination of insecticide, sex attractant and its holder, funnel and baffle, and the influence of trap color, cleanliness, position in the tree, and holder on the number of catches.

Multi-Pher®-~~1~~ 2 Multi-Pher®-~~2~~ 1 Multi-Pher®-3

Figure 1. Three models of the Multi-Pher® trap.

MATERIAL AND METHODS

General experimental conditions

The field trials were conducted in the Gaspé Peninsula (Figure 2), in the Dunières, Baldwin, and Chics-Chocs reserves, and on Mont Saint-Pierre near Sainte-Irène. For each experiment, tests were carried out at two to seventeen sites during the same season, except for two experiments, one of which was repeated over three years at five, three, and twelve sites, respectively, and another which was repeated for two years at eight and twelve sites, respectively.

Sites were chosen in mature stands on the basis of balsam fir (*Abies balsamea* [L.] Mill.) composition (70% or more) and the density of SBW larval populations. At most sites, balsam fir was associated with a small percentage of white spruce (*Picea glauca* [Moench] Voss), black spruce (*P. mariana* [Mill.] BSP), or hardwood species. The larval population density of each site was reported annually by the ministère des Forêts du Québec. It varied from low (1 to 100 larvae/10 m^2 of foliage) to extreme (over 650 larvae/10 m^2 of foliage).

At each site, three traps of each type to be tested were installed. In tests carried out within forest stands, the various types of traps were alternated 40 m apart along a line parallel to a road, 40 m inside the stand. The traps were attached to 30 to 60 cm long dead balsam fir branches located about 1.5 m from the ground. In some tests, traps were also placed along forest roads; they were hung alternately from live branches in the crown of balsam firs 40 m apart, approximately 9 m above the ground.

To hang the traps in tree crowns, a four-segment pole was used (Figures 3a and 3b). At the top end of the pole was a Multi-Pher® trap container, the bottom of which was fitted with a plastic tube into which the tip was snugly inserted. A hook was inserted into the two anchor points of the trap, on the top of the cover. Once the trap was placed in the container, the hook opening was turned in the same direction as a piece of tape placed vertically on the

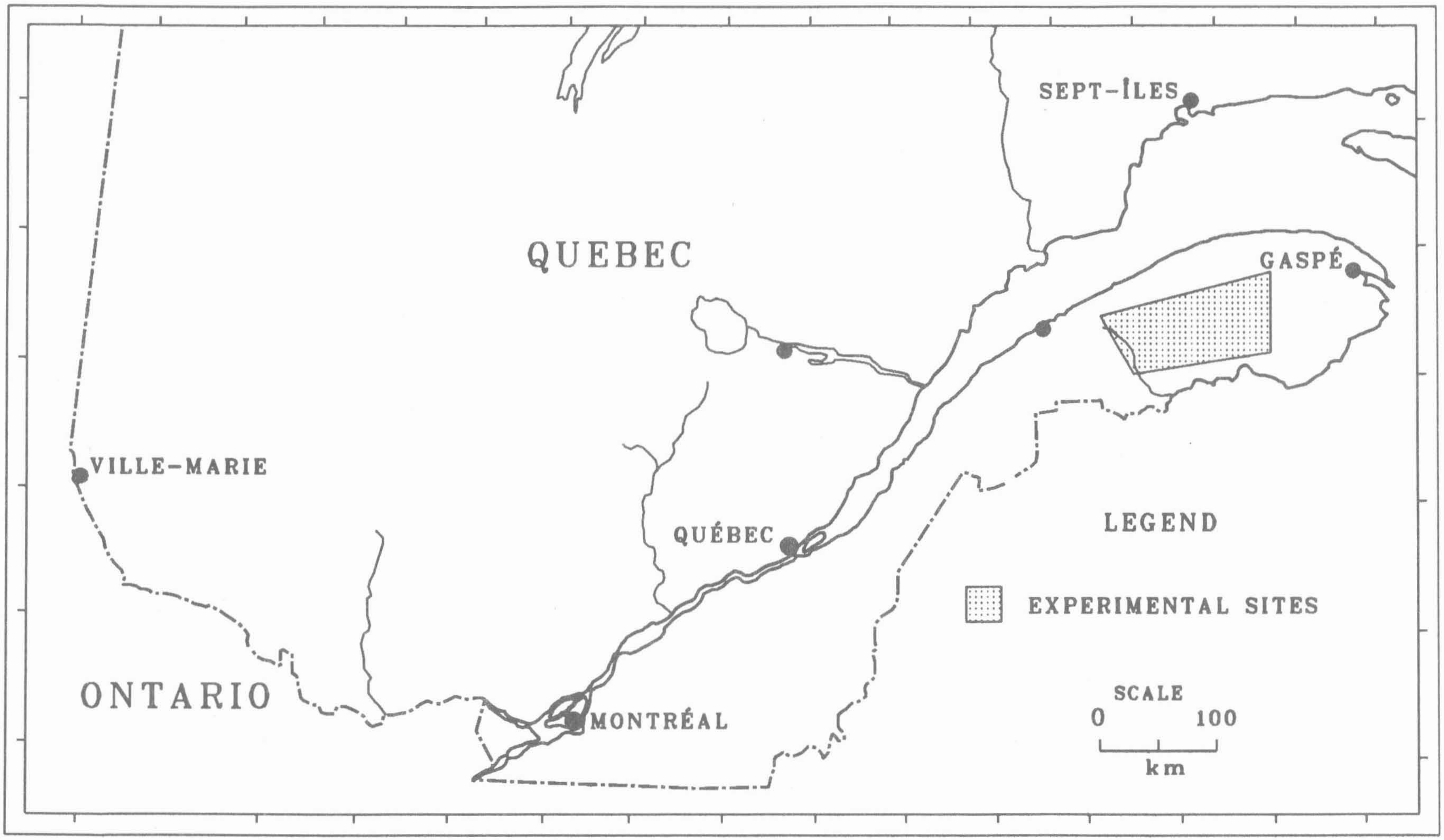

Figure 2. Location of experimental sites in the Gaspé Peninsula.

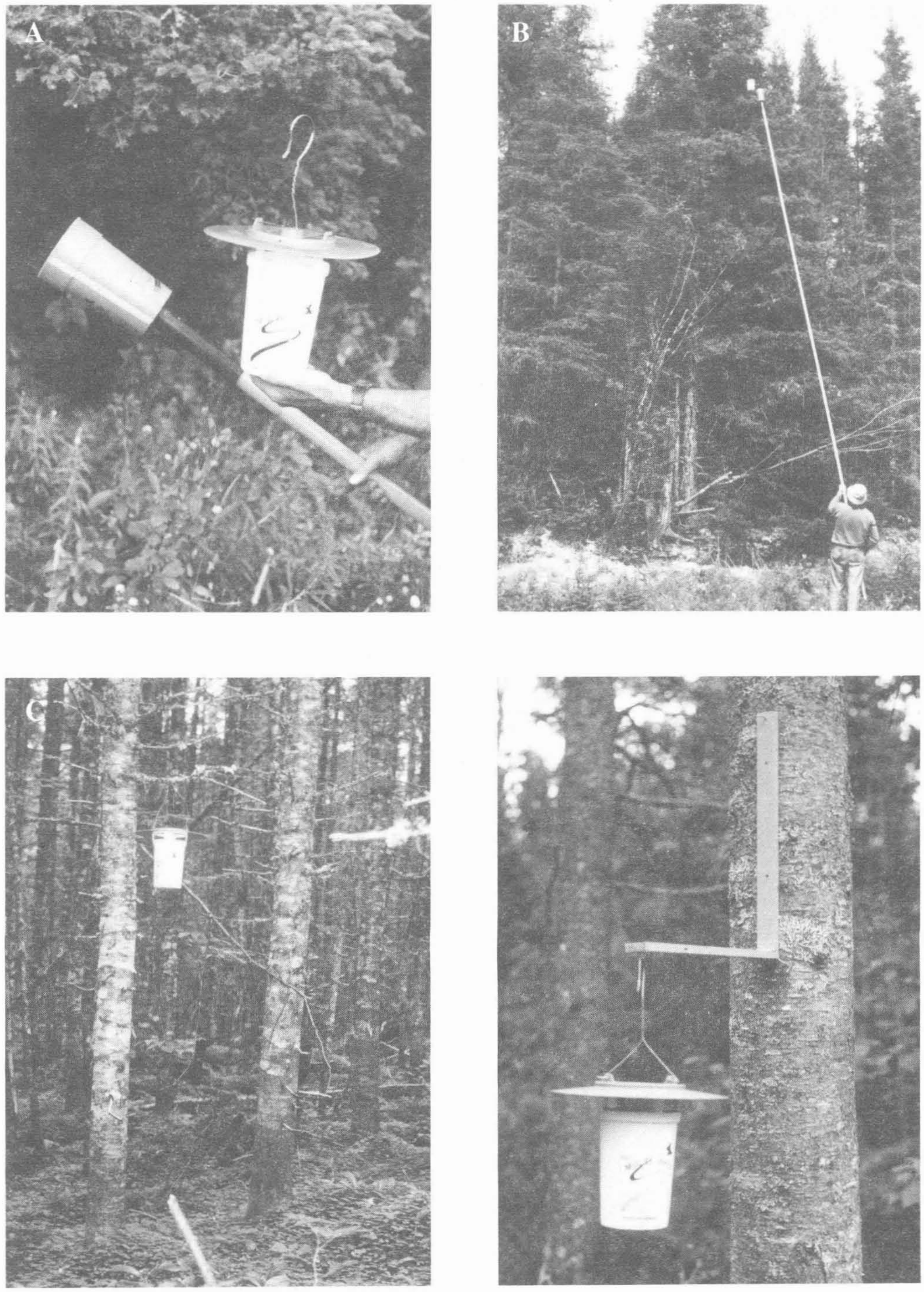

Figure 3. Technique for installing the Multi-Pher® trap in the crown of a balsam fir: a) Container on pole and trap with hook; b) Trap in crown; c) Trap 1.5 m from ground on dry branch; d) Trap on 45-cm holder.

side of the container attached to the pole. The operator could thus determine the direction of the hook opening into which a branch was inserted.

Unless otherwise indicated, the experiments described in this report were carried out within forest stands, using clean white plastic traps (model Multi-Pher®-1) equipped with a funnel and a lure mounted on a holder attached to the centre of the underside of the cover by an entomological pin (Figure 1, Model 1). The cylindrical lure measured 4 mm in diameter by 10 mm in length (Figure 4f). It is made of polyvinyl chloride impregnated with a 0.03% concentration of the sex attractant blend (95 : 5 (E: Z) -11- tetradecenal) (Fulure, Science Productivity Council, Fredericton, New Brunswick). The lures were kept at 1°C until the traps were installed. These traps had no baffle. In most tests, 1/4 of a Vapona™ strip hung from the funnel made it possible to capture the moths without damaging them.

Each time the traps were emptied, the captured moths were placed in paper bags (No. 10, St. Lawrence Paper Bag Ltd.). The fairly large opening of these bags made it possible to insert the trap container into the bag where it could be emptied without losing any specimens. The bags were first identified with a stamp giving site and trap identification, date collected, number of SBW males captured, and number of other insect species. The bags were closed with staples or adhesive tape, sorted by site, and sent to the laboratory for counting and identification of the insects collected.

The moths were counted as follows. When there appeared to be fewer than 100 specimens, they were counted by spreading the moths on a sheet of white paper or cardboard. If there appeared to be more than 100 male moths, numbers were estimated using the weighing method (Allen et al. 1986b).

In all tests, the variance of the natural logarithm of the number of captures was analyzed according to the model dictated by the experimental design; the logarithmic transform stabilized the variance of the residuals and improved the normality of their distribution. In most cases, the model was mixed, with more than one error term. In such cases, Milliken and Johnson (1984) recommend reducing the random part of the model by

Figure 4. Multi-Pher®-1 trap: a) Container; b) Cover; c) Funnel; d) Baffle; e) Lure holder (segments); f) Lure; g) Vaportape II™ insecticide.

eliminating random effects whose variance is not significant at the 10% level and then analyzing the fixed part. The imbalance of the design sometimes required that the denominator of certain by eliminatingF-statistics be estimated using linear combinations of mean squares, and their degrees of freedom approximated by Satterthwaite's method. The averages are shown on their arithmic scale along with the standard errors of relevant differences.

Specific conditions of each study

Experiment 1: Three models of the Multi-Pher® trap

In Experiment 1, the effectiveness of three models of the Multi-Pher® trap was compared at two locations: in the crown of fir trees along forest roads (two sites) and within stands along a straight line, 1.5 m from the ground (five sites). In the part of this test carried out in forest stands there were, exceptionally, five traps per model at each site.

The hypothesis was that Model 1 was better than the other two models (Figure 1) (Jobin and Coulombe 1988). It was also believed that trapping efficacy would be greater if traps were placed in the crown rather than 1.5 m from the ground. Statistical tests were set up accordingly.

Experiments 2 and 3: The sex attractant and its holder

In 1988, Fulure was compared with a similar lure marketed under the brand name Biolure® (Consep™ Membranes Inc., Oregon, U.S.A.). Tests were carried out at six sites (Experiment 2) with three traps of each type alternating in the crown of balsam firs. The chemical composition of Biolure® is the same as that of Fulure, but the pheromone is mounted in a capsule formed mainly of two membranes, one of which is permeable.

In Experiment 3, two lure mounting systems were compared at two sites where five traps were installed with a lure holder, and five traps in which the lure, mounted on an entomological pin, was fastened to the underside of the cover using silicone. These tests were carried out with traps placed in the crown of balsam firs located along forest roads in alternating positions.

Experiments 4, 5, and 6: Insecticide

The insecticide suspended in the trap kills moths quickly for more accurate identification and counting. Three experiments were carried out to study the effect of insecticide in the trap (Experiment 4), insecticide brand (Experiment 5), and concentration (Experiment 6). Six traps were placed in an alternating position in the crown of balsam fir trees located along forest roads.

Experiment 4 was conducted at two sites, each with three control traps and three traps containing dichlorvos (Figure 4g). This insecticide is the active ingredient in products sold commercially under Vapona™ and Vaportape II™ brand names. A complete Vapona™ strip contains 19.2% A.I. of dichlorvos, while Vaportape II™ contains 9.95% A.I.

In 1985, 1986, and 1987 (Experiment 5), Vapona™ (1/4 strip), and Vapona II™ in insecticidal strips were compared at five, three, and twelve sites, respectively.

Experiment 6 was conducted at six sites in 1987. Two sizes of Vapona™ strip pieces (1/4 and 1/8 of a Vapona™ strip) were compared.

Experiments 7, 8, 9, and 10: Funnel, baffle, and trap color, position, and cleanliness

Traps with or without a funnel (Figure 4c) were compared in a test at two sites where five traps of each type were installed (Experiment 7) in alternating positions, 1.5 m from the ground.

The effectiveness of a baffle (Figure 4d) was assessed at seventeen sites (Experiment 8). The baffle is made of two transparent 1.5 mm thick plexiglass pieces that fit into each other at the centre, thus making four winglets with their edges resting against the sides of the ingress holes on the side of the container and their lower ends on the edges of the funnel that goes into the container. The winglets form an obstacle that deflects the moth's flight when it hits the baffle. Six traps were installed at each site, three with and three without a baffle, in the crown of balsam firs along forest roads. Catches were collected throughout the flight period of *C. fumiferana*.

The influence of trap color on catch results was assessed by comparing white and green Multi-Pher®-1 traps of the same model. It was hypothesized that green traps, which are less likely to be stolen or vandalized, would be as effective as white ones. Experiment 9 involved twelve sites. Six traps, three of each color, were hung in the crown of fir trees along forest roads, and six others, three of each color as well, were placed 1.5 m from the ground, inside the stand.

A test was carried out at six sites to determine whether the cleanliness of the Multi-Pher®-1 trap or any traces of the sexual pheromone remaining in the plastic after use had an influence on trap catch results (Experiment 10). At each site, three new traps and three used, uncleaned traps were placed alternately in the crown of balsam firs along forest roads at each site.

Experiments 11 and 12: Trap holder

The purpose of the last two experiments, the first carried out in 1986, and the second in 1988 and 1989, was to evaluate a trap holder and trap distance from the bole. In both experiments, the trap holder was made of two pieces of wood 4 cm wide and 1 cm thick. They were fastened together at one end with a hinge. One section of the device was nailed to the trunk of the fir 1.5 m from the ground, while the other had a ring hook screwed to the free end from which the trap was hung (Figure 3d). In the 1986 field trial (Experiment 11), the trap holder measured 70 cm; in 1988 and 1989 (Experiment 12), it measured 45 cm. The holder made it possible to hang the trap at a constant distance from the ground and to the tree bole. Once moth emergence was completed, the holder was folded to be reused the following year. Traps catch results were compared with those of traps hung from a dead branch (Figure 3c) located approximately 1.5 m from the ground on a balsam fir bole. Experiment 11 was carried out at twelve sites in 1986 and Experiment 12 at eight sites in 1988 and twelve sites in 1989.

RESULTS AND DISCUSSION

Experiment 1: Three models of the Multi-Pher® trap

Model 1 attracted 86% more SBW males than the two other models (P = 0.0006, Table 1); trap catches in these two models were equivalent (P = 0.2806). The number of males in traps placed in the crown was much higher than the number captured with traps 1.5 m from the ground (P = 0.0237), but it is impossible to determine whether this was due to the trap position in the crown or to the roadside position of the trees. These two effects are confounded. Differences between average catches of the three Multi-Pher® trap models

Table 1. Analysis of variance of the natural logarithm of number of male spruce budworms caught, and averages, on logarithmic scale, by height and trap model

Source of variation	Degrees of freedom	Mean squares	P
Height	1	8.8141	0.0237[a]
Site (Height)	5	1.0416	0.0296
Model	2	3.3812	0.0030
Model 1 vs others	(1)	6.3658	0.0006[1]
Model 2 vs 3	(1)	0.4082	0.2806
Height x Model	2	0.1174	0.6962
Site x Model (Height) (Error B)	10	0.2601	0.0001
Error C	54	0.0395	
Total	74		

Model	Crown	1.5 m from ground	Average
Multi-Pher®-1	6.91[b] (1001)[c]	6.36 (578)	6.63 (761)
Multi-Pher1®-2	6.28 (551)	5.55 (257)	5.91 (369)
Multi-Pher®-3	6.51 (670)	5.68 (294)	6.10 (444)
Average	6.56 (709)	5.86 (352)	

[a] Unilateral test;
[b] Standard error (s.e.) of difference between two models at 1.5 m = 0.270;
s.e. of difference between two models in the crown = 0.177;
s.e. of difference between two models at different heights or between traps of the same model at different heights = 0.325;
[c] Median number of captures.

were the same whether they had been placed in the crown of firs along forest roads, or within the stand 1.5 m from the ground ($P = 0.6962$).

Experiments 2 and 3: The sex attractant and its holder

Biolure® attracted approximately three times more moths than Fulure ($P \leq 0.0001$, Table 2). This difference was constant from site to site ($P = 0.5629$).

Table 2. Analysis of variance of the natural logarithm of number of male spruce budworms caught, and averages, on logarithmic scale, by sex attractant brand

Source of variation	Degrees of freedom	Mean squares	P
Site	5	0.0269	0.2806
Attractant	1	1.8258	0.0001
Error	28[a]	0.1047	
Total	34		
Sex attractant		**Average**	
Fulure		2.39 (11)[b]	
Biolure®		2.85 (17)	
Difference		-0.46	
Standard error (difference)		0.048	

[a] There were no captures in a trap with Biolure® at one site; the error combines the Site x Attractant interaction, which was not significant at the 10% level, and the intra-site error between traps with the same attractant;
[b] Median number of captures.

The number of moths captured seems to be just as high for traps with a lure holder as for those where the lure was fastened with an entomological pin ($P = 0.2202$, Table 3). The same tendency was observed at all sites ($P = 0.6343$). The latticework mount minimizes contact with the lure when the trap is assembled and installed in forest stands. It also protects the lure from direct contact with the moth when it enters the trap.

Experiments 4, 5, and 6: Insecticide

In traps containing an insecticide, four times as many insects were collected, on average, than with control traps (Experiment 4, Table 4). However, this difference was not significant

Table 3. Analysis of variance of the natural logarithm of number of male spruce budworms caught, and averages, on logarithmic scale, with and without sex attractant holder

Source of variation	Degrees of freedom	Mean squares	P
Site	1	0.0066	0.4857
Attractant	1	0.0211	0.2202
Error	17[a]	0.0130	
Total	19		
Sex attractant holder		**Average**	
With		2.76 (16)[b]	
Without		2.70 (15)	
Difference		0.06	
Standard error (difference)		0.051	

[a] The error combines the Attractant x Site interaction, which was not significant at the 10% level, and the intra-site error between traps with the same sex attractant;
[b] Median number of captures.

Table 4. Analysis of variance of the natural logarithm of number of male spruce budworms caught, and averages, on logarithmic scale, with and without insecticide

Source of variation	Degrees of freedom	Mean squares	P
Site	1	8.38	0.2261
Insecticide	1	11.23	0.1973
Site x Insecticide (Error A)	1	1.15	0.0802
Error B	8	0.29	
Total	11		
Insecticide	**Site 1**	**Site 2**	**Average**
With	5.3 (193)[b]	4.2 (67)	4.74 (114)
Without	3.9 (52)	1.7 (5)	2.80 (16)
Difference	1.4	2.5	1.94
Standard error (difference)[a]	0.89	0.89	0.620

[a] These standard errors are based on one degree of freedom only;
[b] Median number of captures.

Table 5. Analysis of variance of the natural logarithm of number of male spruce budworms caught, and averages, on logarithmic scale, for Vapona™ (19.2% A.I.) and Vaportape II™ (9.95% A.I.)

Source of variation	Degrees of freedom	Mean squares	P
Insecticide	1	5.9762	0.0001
Site (Year)	19	5.6491	0.0001
Error	109[a]	0.1207	
Total	129		

Insecticide	Average
Vapona™	5.58 (249)[b]
Vaportape II™	5.09 (162)
Difference	0.49
Standard error (difference)	0.061

[a] The error combines the Insecticide x Site (Year) interaction, which was not significant at the 10% level, and the intra-site error between traps with the same insecticide;
[b] Median number of captures.

Table 6. Analysis of variance of the natural logarithm of number of male spruce budworms caught, and averages, on logarithmic scale, by dose of Vapona™ (1/4 and 1/8 of an insecticide strip)

Source of variation	Degrees of freedom	Mean squares	P
Site	5	0.8390	0.0001
Dose	1	0.0009	0.9002
Error	29[a]	0.0575	
Total	35		

Dose of Vapona™	Average
1/4 strip (5 g of dichlorvos)	6.52 (678)[b]
1/8 strip (2.5 g of dichlorvos)	6.53 (685)
Difference	-0.01
Standard error (difference)	0.080

[a] The error combines the Dose x Site interaction, which was not significant at the 10% level, and the intra-site error between traps with the same insecticide dose;
[b] Median number of captures.

(P = 0.1973); it did not appear to be stable from one site to another (P = 0.0802). The effect of trap type on the number of captures was thus tested against the interaction between sites and trap type which has only one degree of freedom; such a test is not powerful enough to detect even a major difference. Within each site, the number of moths was much higher in traps containing an insecticide.

In Experiment 5, which was performed at 20 sites over a period of three consecutive years, the number of captures was approximately 1.7 times higher with Vapona™ than with Vaportape II™ ($P \leq 0.0001$, Table 5). The difference observed in the previous experiment seems all the more plausible since the two insecticide concentrations have different effects.

The number of male moths captured was about the same for the two dichlorvos concentrations compared in Experiment 6, i.e. 1/4 and 1/8 of a Vapona™ strip $P = 0.9002$ (Table 6). The statistical test is based on 29 degrees of error freedom and its power is unquestionable. This suggests that there is an optimum quantity of insecticide beyond which trap efficiency cannot be improved. This level was apparently reached with 19.2% A.I., unlike the Vaportape™ which contains only 9.95%.

Experiments 7, 8, 9, and 10: Funnel, baffle, and trap color, position and cleanliness

The funnel and baffle increased the number of male moths captured (Experiments 7 and 8, Tables 7 and 8, $P \leq 0.0001$ in both cases). The increase due to the presence of a funnel was of the order of 500%, while that related to the baffle was 48%. Traps placed

Table 7. Analysis of variance of the natural logarithm of number of male spruce budworms caught, and averages, on logarithmic scale, with and without a funnel

Source of variation	Degrees of freedom	Mean squares	P
Site	1	0.0081	0.7864
Funnel	1	13.0544	0.0001
Error	17[a]	0.1072	
Total	19		

Funnel	Average
With	5.83 (342)[b]
Without	4.22 (68)
Difference	1.62
Standard error (difference)	0.146

[a] The error combines the Funnel x Site interaction, which was not significant at the 10% level, and the intra-site error between traps with or without a funnel;
[b] Median catch.

Table 8. Analysis of variance of the natural logarithm of number of male spruce budworms caught, and averages, on logarithmic scale, with and without a baffle

Source of variation	Degrees of freedom	Mean squares	P
Site	16	8.8058	0.0001
Baffle	1	3.7255	0.0001
Error	84[a]	0.0681	
Total	101		

Baffle	Average
With	7.58 (1950)[b]
Without	7.19 (1331)
Difference	0.38
Standard error (difference)	0.052

[a] The error combines the Baffle x Site interaction, which was not significant at the 10% level, and the intra-site error between traps with or without a baffle;
[b] Median catch.

Table 9. Analysis of variance of the natural logarithm of number of male spruce budworms caught, and averages, on logarithmic scale, by trap color and position

Source of variation	Degrees of freedom	Mean squares	P
Site	11	15.3872	0.0001
Position	1	92.2305	0.0001
Site x Position (Error A)	11	0.5097	0.0733
Color	1	8.7197	0.0001[a]
Color x Position	1	0.0508	0.6557
Site x Color (Position) (Error B)	22	0.2487	0.0274
Error C	96	0.1383	
Total	143		

Position	Color		Average	Difference
	White	Green		
Crown	6.14 (464)[b]	5.68 (294)	5.91 (370)	
1.5 m from ground	4.58 (97)	4.05 (57)	4.31 (75)	
Average	5.36 (212)	4.87 (130)		0.49[c]
Difference			1.60[d]	

[a] Unilateral test;
[b] Median number of captures;
[c] Standard error (s.e.) = 0.118;
[d] s.e. = 0.168.

Table 10. Analysis of variance of the natural logarithm of number of male spruce budworms caught, and averages, on logarithmic scale, for new and used traps

Source of variation	Degrees of freedom	Mean squares	P
Site	5	0.3045	0.0590
Cleanliness	1	0.0669	0.4712
Error	29[a]	0.1254	
Total	35		
Cleanliness		Average	
New		5.99 (401)[b]	
Used		5.91 (368)	
Difference		0.09	
Standard error (difference)		0.118	

[a] The error combines the Cleanliness x Site interaction, which was not significant at the 10% level, and the intra-site error between new and used traps;
[b] Median number of captures.

in the tree crowns captured more moths than those placed 1.5 m from the ground (Experiment 9, $P \leq 0.0001$, Table 9), and the white Multi-Pher®-1 was more effective than the green one (63%, $P \leq 0.0001$). Trap cleanliness did not seem to affect the number of male moths captured (Experiment 10, $P = 0.4712$, Table 10).

Experiments 11 and 12: Trap holder

Experiment 11, conducted in 1986 to compare trap catch results in traps suspended from dead branches and those in traps fastened to 70 cm holders, suggests that trap catches decrease when the trap is suspended from a 70 cm holder ($P \leq 0.0001$, Table 11). However, Experiment 12, conducted in 1988 and 1989 with a 45 cm instead of a 70 cm holder, showed no significant difference between average number of males in traps hanging from branches and those in traps fastened to a holder ($P = 0.1841$, Table 12). The holder should then be about the same length as the branches to yield the same number of trap catches. In an insect pest monitoring network, sites are often permanent, and it would be advantageous to use holders that can remain in place from one season to another. Moreover, it is often difficult to find trees with a dead branch 1.5 m from the ground on which to hang the trap.

Table 11. Analysis of variance of the natural logarithm of number of male spruce budworms caught, in 1986, and averages, on logarithmic scale, by type of holder

Source of variation	Degrees of freedom	Mean squares	P
Site	11	9.2099	0.0001
Support	1	3.5502	0.0001
Error	59[a]	0.1571	
Total	71		
Support		Average	
Branch		4.00 (55)[b]	
Support 70 cm		3.56 (35)	
Difference		0.44	
Standard error (difference)		0.093	

[a] The error combines the Support x Site interaction, which was not significant at the 10% level, and the intra-site error between traps hung from the same type of holder;
[b] Median number of captures.

Table 12. Analysis of variance of the natural logarithm of number of male spruce budworms caught, in 1988-1989, and averages, on logarithmic scale, by type of trap holder

Source of variation	Degrees of freedom	Mean squares	P
Support	1	0.3631	0.1841
Site (Year)	19	3.6072	0.0001
Error	99[a]	0.2029	
Total	119		
Support		Average	
Branch		3.52 (34)[b]	
Support 45 cm		3.41 (30)	
Difference		0.11	
Standard error (difference)		0.082	

[a] The error combines the Support x Site (Year) interaction, which was not significant at the 10% level, and the intra-site error between traps hung from the same type of holder;
[b] Median number of captures.

CONCLUSION

The Multi-Pher®-1 trap proved to be the most effective of the three Multi-Pher® models. The average number of males captured was 86% higher than that for the two other models tested.

The Biolure® synthetic sex attractant was 158% more effective than Fulure.

The use of insecticide quadrupled the number of captured males. The number of males captured was 70% higher with 1/4 of a Vapona™ strip (19.2% of A.I.) than with Vaportape II™ which contains only 9.95% of A.I., but 1/4 of a Vapona™ strip was no more effective than half that dose, i.e., 1/8 of a strip.

The use of a funnel increased by 5 the average number of males captured and the use of a baffle increased it by 1.5. Approximately five times more male SBW moths were captured in fir tree crowns as compared with 1.5 m from the ground. The average trap catch results were approximately 63% higher in white traps than in green. Trap cleanliness had no effect on trap catch results.

Lastly, the 45 cm mount nailed to the tree truck was just as effective as a dead branch of the same length. This was not true of the 70 cm mount, where approximately two male SBW moths were captured for every three caught in control traps hung from 30 to 60 cm branches.

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APPENDIX 1

List of Lepidoptera species other than *C. fumiferana* caught in the Multi-Pher®-1 trap network installed in Quebec from 1984 to 1988.

The trapping period for *C. fumiferana* lasts six weeks, from early July to mid-August, in eastern Quebec, and from the last week of June to the first week of August in the central and western parts of the province.

During this period, other species of insects were also captured in the Multi-Pher®-1 trap used each year in the spruce budworm trapping network of the ministère des Forêts du Québec. They were mainly Lepidoptera species but Diptera and Coleoptera were also captured.

The list that follows shows the Lepidoptera species caught in the Quebec monitoring network traps between 1984 and 1988. The relative abundance of captures of each species is represented by the symbol +. The number of captures of two Geometridae, *Campaea perlata* (Gn.) and *Lambdina fiscellaria* (Gn.) is often high and may be up to 50 or more moths per trap in certain cases. Of this number, one or two specimens were females and the others males, indicating that this was not an accidental catch but probably due to the behavior of these two species which mate in sheltered areas. It is also plausible that the female releases a sex pheromone before being killed by the insecticide, thus drawing males to the trap.

Latin name	Year/frequency				
	1984	1985	1986	1987	1988
Acronicta sp.		+			
Amathes bicarnae (Gn.)	+	+			
Anacamptodes ephyraria (Wlk.)	+				
Apotomis funerea (Neyr.) *Aphavia youngana*	+				
Archips argyrospila (Wlk.)	+				
Autographa ampla (Wlk.)	+	+	+	+	+
Autographa bimaculata (Steph.)		+			
Autographa precationis (Gn.)		+			
Besma quercivoraria (Gn.)		+			
Caenurgina crassiuscula (Haw.)		+			
Campaea perlata (Gn.)	++++	++	+++	++++	++++
Caripeta angustiorata Wlk.			+	+	+
Caripeta divisata Wlk.	+	+	+++	++	+++
Catocala crataegi Saund.		+			
Choristoneura rosaceana (Harr.)	++++	+	++	+	+
Clepsis persicana (Fitch)	+				
Croesia curvalata (Kft.)	++	+			
Croesia semipurpurana (Kft.)			+++	++++	+
Dioryctria reniculelloides Mut. & Mun.		+			
Dysstroma sp.		+	++	+	
Dysstroma walkerata					+
Enargia decolor (Wlk.)	+++	+	+	+	+
Enargia infumata (Grt.)		+		+	
Epirrita automnata (Bkh.)		+			
Eugonobapta nivosaria (Gn.)		+			
Eulithis (lygris) *explanata* Wlk.	+		+	+	+
Euphyia unangulata intermediata (Gn.)		+			
Feltia herilis (Grt.)	++	+			
Graphiphora haruspica (Grt.)					
Halisidota tessellaris (J.E. Smith)					
Ipimorpha pleonectusa Grt.		+			
Itame loricaria (Evers.)	+				
Lacinipolia olivacea (Morr.)		+			

Latin name	Year/frequency				
	1984	1985	1986	1987	1988
Lambdina fiscellaria (Gn.)	++++	++	++	++	+++
Leucania sp.		+			
Macrobotys pertextalis (Led.)		+			
Nadata gibbosa (J.E. Smith)		+			
Nematocampa limbata (Haw.)	++++	++++	+++	+	+
Palthis angulalis (Hbn.)		+	+++	++	+
Pandemis limitata (Rob.)				+	+
Pandemis sp.	+				
Phlogophora periculosa (Gn.)		+	++	+	+
Plusia aeroides (Grt.)		+			
Plusia putnami Grt.		+			
Probole amicaria (H.-S.)		+			
Prochoerodes transversata (Dru.)				+	+
Pseudothyatira cymatophoroides (Gn.)	+	++	+		+
Pseudothyatira expultrix (Grt.)			+		+
Pyralidae	+				
Scopula sp.	+				
Semiothisa porcelaria indicataria Wlk.	+	+			
Semiothisa signaria dispuncta Wlk.			+	+	+
Syngrapha alias (Ottol.)	++				
Syngrapha rectangula (Kby.)					
Thymelicus lineola Ochs.	+		++	+	+
Xanthorhoe algidata (Mosch.)		+			
Zanclognatha sp.		+			