WINDTUNNEL AND FIELD OBSERVATIONS OF WESTERN SPRUCE BUDWORM[1] RESPONSES TO PHEROMONE-BAITED TRAPS[3]

N. ANGERILLI[2] AND J. A. McLEAN
Faculty of Forestry
University of British Columbia
Vancouver, B.C. V6T 1W5

ABSTRACT

Five trap designs, the Pherocon 1CP, a triangular trap, dome trap, double cone trap and Kendall trap were evaluated for capturing the western spruce budworm, *Choristoneura occidentalis* Freeman, both in a laboratory-based windtunnel and in an infested stand. Neutral density smoke tests showed the effects of orientation to wind on plume formation as well as highlighting plume structure around larger traps. Moth capture rates in the windtunnel did not always correlate with capture rates under field conditions.

INTRODUCTION

Pheromone-baited traps have proven useful for monitoring many species of insects and are often integral parts of pest management programmes (Kennedy 1981). Such traps are most useful if they are consistent in their catches and reflect the relative abundance of the insect being monitored. Several designs of sticky traps have been evaluated against the spruce budworm, *Choristoneura fumiferana* (Clem.), (Sanders 1978; Houseweart *et al.* 1981). Omnidirectional high capacity traps have also been tested for moths (Steck and Bailey 1978; Struble 1983) with several designs recently developed and tested specifically against the spruce budworm (Ramaswamy and Carde 1982; Kendal *et al.* 1982).

One difficulty with testing traps in the field is determining how many insects were attracted but not captured. That is, it is difficult to know how "efficient" a given trap design is except relative to other traps.

The objective of this study were to observe and measure the absolute efficiency of several trap designs to attract and capture male western spruce budworm (WSBW) *C. occidentalis* Freeman, under laboratory conditions in a windtunnel; to relate this efficiency to the size and shape of emitted pheromone plumes; to make predictions, based on these results, of the field efficiency of the tested traps; and to test the laboratory predictions in the field.

MATERIALS AND METHODS

A 4.88 m long windtunnel with 1.2 m square cross section was built and calibrated for wind speeds from 0 to 1.4 m s^{-1}. The front side and top of the tunnel were of clear acrylic plastic while the back and bottom were fir plywood. Air was drawn through a smooth curve entrance and double screens in order to produce a laminar windflow. Measurements of wind speed demonstrated uniform cross tunnel velocities and the presence of a 2.5 cm still air boundary layer which helped to minimize pheromone contamination of the windtunnel. The end of the tunnel was also screened to prevent escape of insects. Quarter sections of the acrylic panels were hinged at the front and rear of the tunnel to facilitate access for test materials and insects. Air was drawn from the tunnel and expelled to the outside of the building. All tests were conducted at 0.5 m s^{-1}.

The traps tested in the tunnel were the Pherocon 1CP (Zoecon Corp.), a triangular trap (Cory *et al.* 1982), a double cone trap, a dome trap and the Kendall trap (Fig. 1). The first two traps rely on sticky inner surfaces to trap attracted insects while the last three were no-exit type non-sticky traps. In order to visualize the pheromone plume emitted from these traps, an approximation was made by using titanium tetrachloride neutral density "smoke". The $TiCl_4$ was released from half-filled one dram glass vials with a 2 cm long string wick to act as an evaporative surface. The vial of $TiCl_4$ was positioned inside each trap at the same point as the pheromone dispenser. Each trap was tested to determine the smoke plume (and so to infer the pheromone plume) from the trap in line with the wind (180°), crosswind (90°) and at an angle to the wind (45°). The plumes were recorded on panchromatic film and later sketched.

Western spruce budworm from the non-diapausing strain kept at the Pacific Southwest Forest Range Experiment Station at Berkeley, CA, were reared on artificial diet (BioServ® 9769). Pupae were placed into individual containers and kept in a light dark regime of 16 and 8 h with dawn occurring at 2400 h and dusk at 1700 h. Adults were kept under the same regime until three days old when they were used once between 1300 h and 1800 h in flight tests. After testing, the moths were kept for a further 24 h. The data were retained only from those insects that survived.

The synthetic WSBW pheromone, a 92:8 blend of (E) and (Z)-11-tetradecenal (E, Z11-14:A1), was dispensed from 10 μL glass capillaries contained in

---

[1] *Choristoneura occidentalis*; Lepidoptera: Tortricidae.
[2] Present address: Agriculture Canada, Research Station, Summerland, British Columbia V0H 1Z0.
[3] Contribution No. 605, Research Station, Summerland.

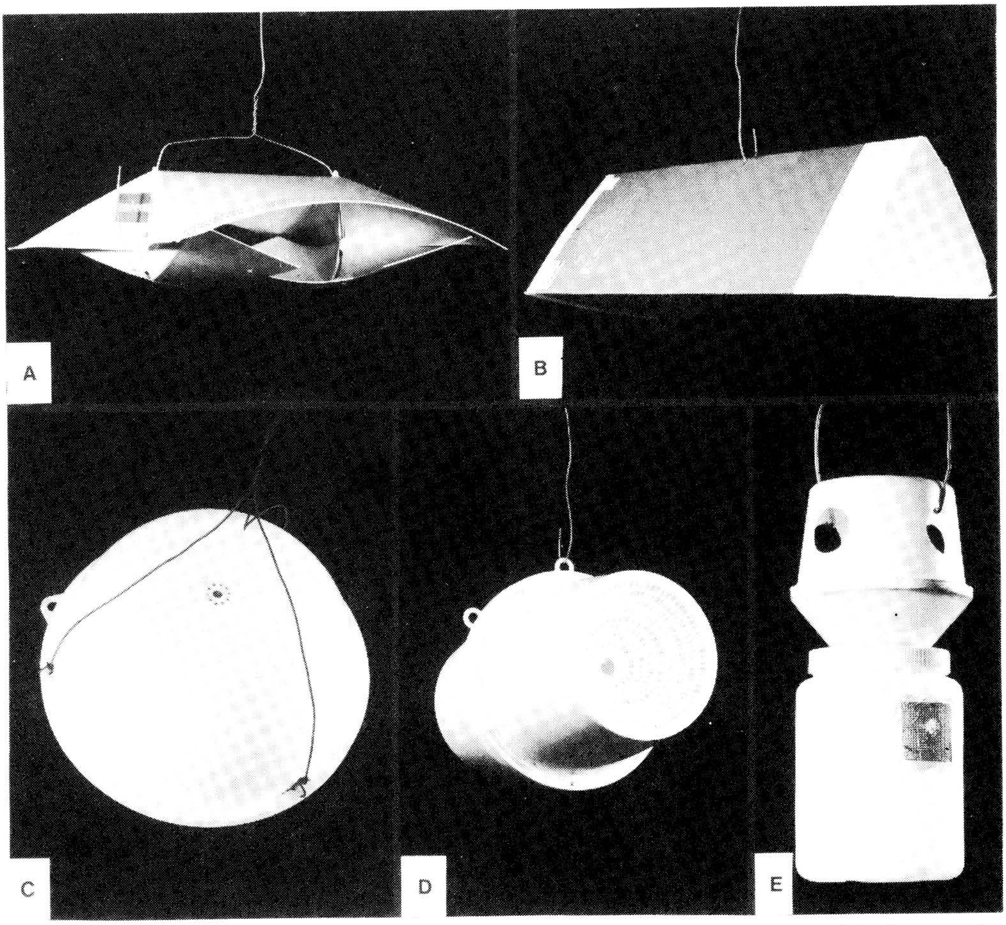

Fig. 1. Traps evaluated in the UBC windtunnel using $TiCl_4$ neutral density smoke; traps A-D also tested for efficiency in capturing WSBW when baited with pheromone; all traps tested in the field, A. Pherocon 1CP trap, B. Triangular trap, C. Dome trap, D. Double cone trap, E. Kendall trap.

an open 1 dr. glass vial. The pheromone test procedure consisted of taking the males out of the controlled environment rearing chambers 0.5 h before the beginning of testing and the pheromone-loaded capillaries out of refrigeration 1 h before testing. The pheromone-baited trap was placed in the tunnel entrance as described for the trap smoke tests. Males were released individually at the opposite end of the tunnel onto a circular glass platform (diameter = 20 cm) so positioned that the moth was in the estimated centre of the pheromone plume. Time-to-flight initiation (latency), time-in-flight, and time-to-capture (where appropriate) after reaching the pheromone source, were recorded in seconds. Males were also scored as being responders or non-responders. Typically, a responder faced into the wind with the longitudinal body axis in line with the wind direction, exhibited pre-flight wing-fanning, and took-off into the wind; the resulting flight line was a zig-zag upwind in the estimated plume region towards the pheromone source on which it landed and exhibited post-flight or pre-mating walking and wing-fanning. A non-responder usually failed to fly although it sometimes faced into the wind or took off downwind.

Traps were tested using three capilaries of E,Z11-14:A1 as this was shown to produce 80% responders, a short latency ($\bar{x}$ = 5.75s, n = 10), and a fast flight time ($\bar{x}$ = 33.9s, n = 10). The three directional traps were tested at the three trap-to-wind angles previously mentioned. The comparative test of the Pherocon 1CP, triangular (apex down), dome, and double cone traps was run as a 4 x 4 latin square in which each trap was tested daily for 4-days using five individually released moths per trap. The test was re-randomized and run a second time.

To test windtunnel predictions of the relative efficiencies of the previously tested traps, a 6 x 6 latin square design experiment was established near

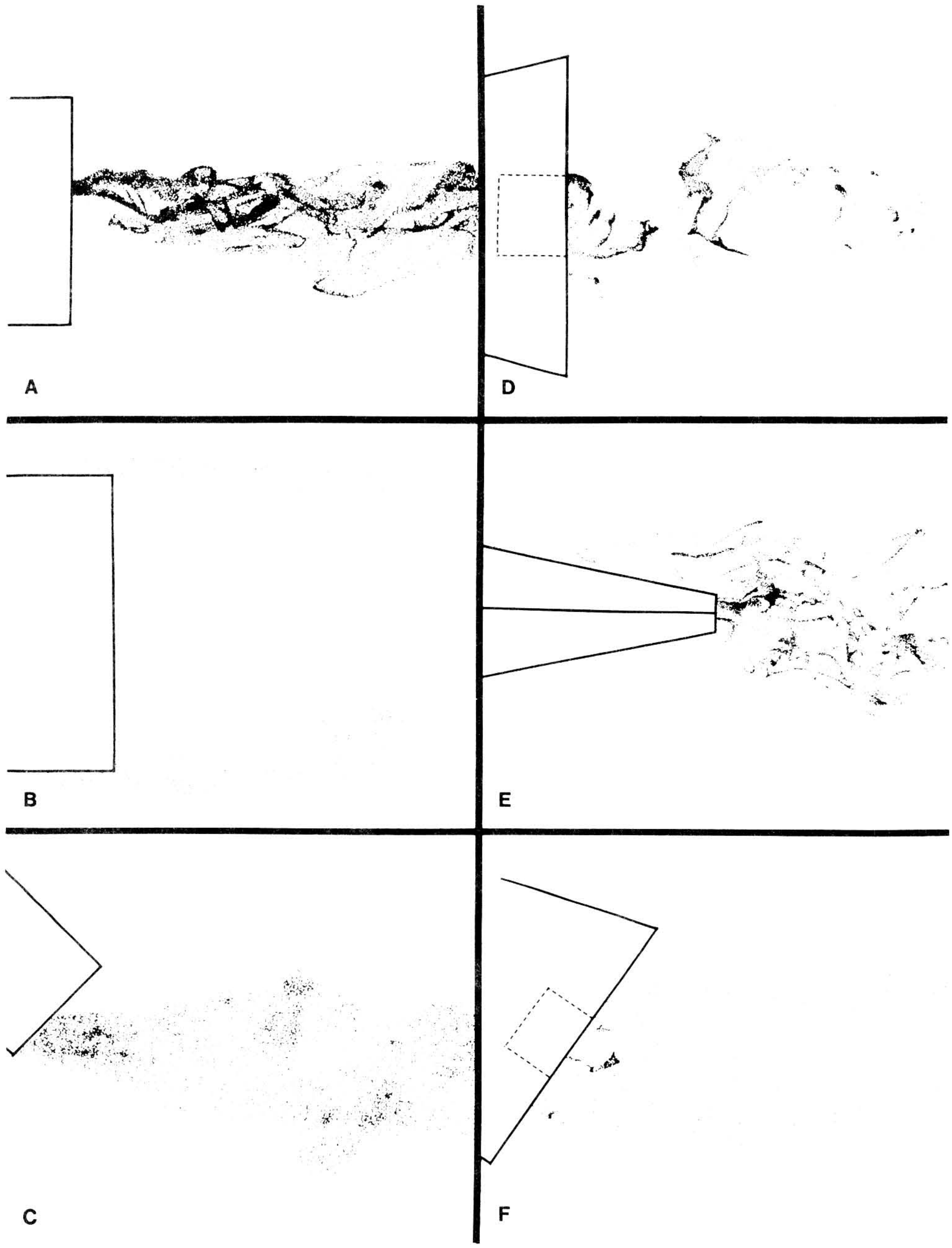

Fig. 2. $TiCl_4$ smoke plumes from two sticky traps: Triangular trap showing A. side view at 180° to wind, B. top view at 90° to wind, and C top view at 45° to wind; and Pherocon 1CP trap showing D, top view in line with wind, E. side view in line with wind and F. top view at 45° to wind.

Oregon Jack Creek, B.C. in an area of moderate to high WSBW infestation. The fifth and sixth traps were the triangular trap with the apex up rather than down and the Kendall trap (Kendall *et al.* 1982). The experiment was initiated on the evening of 16 August 1982 and moths were counted and the traps emptied at mid-day on 17 and 18 August 1982.

RESULTS AND DISCUSSION

The triangular trap produced a relatively dense and stable plume when orientated in line with the wind (Fig. 2A). The trap was always tunnel-tested apex down, however, and after two or three males had struggled in the sticky coating at the trap's entrance it became less sticky due to wing scales coating the sticky surface. Later, males were sometimes seen to enter the trap, continue wing fanning and eventually reemerge from the trap and fly away. When oriented across wind, some smoke was still released (Fig. 2B), and at 45° to the wind a broader, less dense plume was produced (Fig. 2C).

When the Pherocon 1CP trap was in line with the wind it produced a broad (Fig. 2D), dense (Fig. 2E) and easily, tracked plume. The side view (Fig. 2E) shows that there was some "backwash" of the plume and males were often observed walking and fanning in this area prior to entering the trap. A less dense plume was produced when the trap was at 45° to the wind (Fig. 2F). When set out at 90° to the wind, no visible smoke plume was produced.

The dome trap produced a narrow plume but had the advantage of producing it directly from its opening (Fig. 3A), and responding males normally did not find it difficult to find and enter the trap. The novel design of the trap was based on air pressure differences between its bottom and top caused by the longer travel path of air flowing over the top relative to air flowing under the bottom. The pressure difference caused air to flow through holes in the bottom of the trap which was equipped with one-way flap valves into the traps' interior where it became pheromone laden and then emerg-

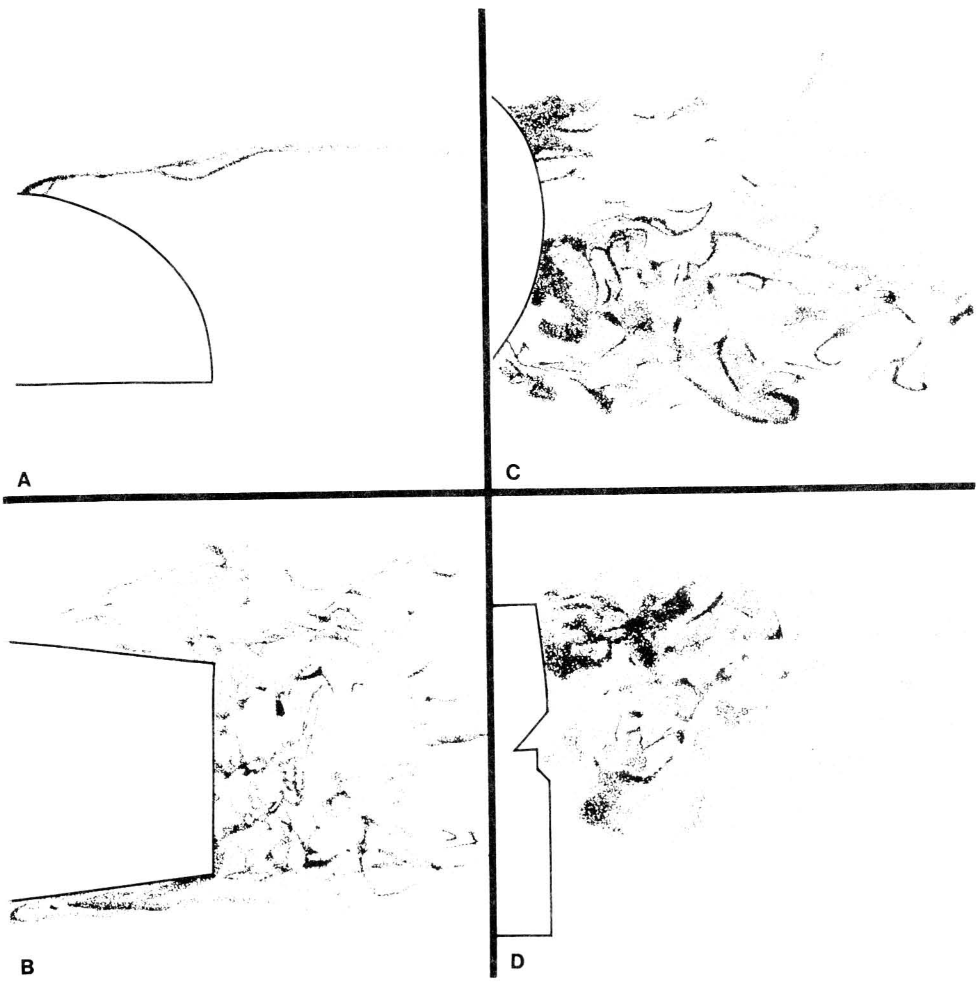

Fig. 3. $TiCl_4$ smoke plumes from A. Dome traps, B. Double cone trap, C. Kendall trap (top view), and D. Kendall trap (side view).

TABLE 1. Comparison of male WSBW responses to pheromone baited traps oriented at 180°, 45° and 90° to the windflow in a windtunnel (n = 10).

Trap design	Orientation windflow (°)	Latency time(s)	Time in flight(s)	Time to capture(s)	Number captured
Triangular	180	5.2 a[1]	24.8 a	55.37 a	8
	45	3.1 a	17.5 a	33.44 a	9
	90	2.9 a	18.1 a	48.12 a	8
Pherocon 1CP	180	1.8 a	14.9 a	21.8 a	10
	45	2.4 a	24.7 a	93.0 b	8
	90	2.5 a	27.5 a	128.1 b	7
Double cone	180	15.1 a	58.9 a	84.3 a	6
	45	14.5 a	20.5 a	86.6 a	5
	90	10.1 a	18.9 a	139.6 a	5

[1]Means followed by the same letter within columns and within trap types are not significantly different (Student Newman-Keuls, $P < 0.05$).

TABLE 2. Mean number of male WSBW caught by four trap designs oriented in line with the wind in a wind tunnel experiment (n = 5 per replicate, 4 replicates run in a latin square randomization configuration). The experiment was run twice.

	Mean catch[1]		
Trap	Run 1	Run 2	Combined
Pherocon 1CP	4.75 a	4.25 a	4.50 a
Triangular (apex down)	3.50 ab	2.50 a	3.00 b
Dome	3.50 ab	3.25 a	3.38 ab
Double cone	2.00 b	2.75 a	2.38 b

[1]Means followed by different letters are significantly different (Student Newman-Keuls, $P < 0.05$).

TABLE 3. Mean number of male WSBW caught by six traps of five designs during two nights in 1982 near Oregon Jack Lake, B.C.

Trap	Mean catch ± s.d.[1] July 16/17	Mean catch ± s.d.[1] July 17/18
Pherocon 1CP	26.5 ± 11.7 a	44.3 ± 21.1 a
Triangular (apex up)[2]	15.3 ± 10.0 b	39.7 ± 13.3 a
Triangular (apex down)	13.3 ± 4.4 b	26.2 ± 5.4 b
Kendall	3.0 ± 2.7 c	16.3 ± 8.8 bc
Doublc cone	2.5 ± 1.5 c	3.8 ± 1.5 c
Dome	0.3 ± 0.5 c	0 ± 0 c
Total moths captured	366	782

[1]Data transformed to X^1 = log (X+1) prior to analysis of variance. Means not followed by the same letter are significantly different (Student Newman-Keuls test, $P < 0.05$).

[2]Two of the six traps became inoperative during the first night, but were repaired for the second.

ed through a single hole in the top of the trap. The double cone trap produced a much broader plume with much back-flow over the outside of the trap (Fig. 3B) up to the central connecting ring. This backflow could result in considerable contamination of the outside of the trap. When male WSBW landed in this area they would walk and continue to wing-fan for an extended period and occasionally enter the trap if they encountered the entrance. The Kendall trap generated a broad plume (Fig. 3C) which also may have contaminated the outside of the collecting jar (Fig. 3D). Certainly many males fanned extensively over the outside of the collecting jar without locating the entrances to the trap. Moths also readily walked out of this trap rather than dropping into the collecting jar.

In the first series of pheromone experiments in the windtunnel (Table 1) it was seen that the triangular trap captured more than 80% of the test insects and had low latency periods which confirmed the adequate plume formation seen in the tunnel. These results were consistent for all trap orientations tested. Results for the Pherocon 1CP trap in line with the wind were the best obtained, with the smallest latency time, least time in flight, fastest time-to-capture, and all the male WSBW captured. This trap was sensitive to cross-wind orientations with less dense plume formation (Fig. 2F) which resulted in extended periods to capture (Table 1).

The plume from the double cone trap was considerably enlarged when the trap was oriented in line with the wind. The diffuseness of the plume by the time it crossed the take-off platform might account for the increased latency times (Table 1). The long time-to-capture probably reflected the difficulty of the male WSBW in locating the entrance hole in the perforated end screen in the trap (Fig. 1d).

The Pherocon 1CP was consistently the most effective trap in the windtunnel (Table 2). The results suggested that the dome trap was a promising design and that the double cone trap was consistently inefficient. In the field experiment, the Pherocon 1CP trap consistently captured the most male

WSBW (Table 3) more than double the numbers caught in the best high capacity trap. The one night tests did not really test the high capacity trap function although it is clear that none of the high capacity designs were as effective as the sticky traps. The triangular trap captured more moths when the apex of the trap was uppermost (Table 3). This suggested that the larger landing platform may have provided an important additional entrapment area. The greatest disappointment, was the poor showing of the dome trap. Smoke tests showed that wind patterns within the stands where trapping was carried out were variable and of a much lower velocity than the 0.5 m s^{-1} windspeed used in the windtunnel to calibrate and test the trap.

The results of this study have shown that smoke testing of traps in a windtunnel can provide valuable information on the integrity of plume formation and shape in relation to orientation to the wind. Pheromone-baited traps can be evaluated as to their efficiency but these results will not necessarily be reflected by catches in the same traps under field conditions. The currently used triangular trap appears to be as effective as any other design at low population levels before the trapped moths saturate the traps.

REFERENCES

Cory, H. T., G. E. Daterman, G. D. Daves, Jr., L. L. Sower, R. F. Shepherd and C. J. Sanders, 1982. Chemistry and field evaluation of the sex pheromone of western spruce budworm, **Choristoneura occidentalis**, Freeman. J. Chem. Ecol. 8:339-350.

Houseweart, M. W., D. T. Jennings and C. J. Sanders. 1981. Variables associated with pheromone traps for monitoring spruce budworm populations (Lepidoptera: Tortricidae). Can. Ent. 113:527-537.

Kendall, D. M., D. T. Jennings and M. W. Houseweart. 1982. A large-capacity pheromone trap for spruce budworm moths (Lepidoptera: Tortricidae). Can. Ent. 114:461-463.

Kennedy, J. W. 1981. Practical application of pheromones in regulatory pest management programs. In Mitchell, E. R. (ed) Management of Insect Pests with Semiochemicals — Concepts and Practice. Plenum Press N.Y. pp. 1-12.

Ramaswamy, S. B. and R. T. Carde. 1982. Nonsaturating traps and long-life attractant lures for monitoring spruce budworm males. J. Econ. Entomol. 75:126-129.

Sanders, C. J. 1978. Evaluation of sex attractant traps for monitoring spruce budworm populations (Lepidoptera: Tortricidae). Can. Ent. 110:43-50.

Steck, W. and B. K. Bailey. 1978. Pheromone traps for moths: evaluation of cone trap designs and design parameters. Environ. Entomol. 7:449-455.

Struble, D. L. 1983. Pheromone traps for monitoring moth (Lepidoptera) abundances: evaluation of cone-orifice and omni-directional designs. Can. Ent. 115:59-65.