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Pheromones and dispersal in the management of eastern spruce budworm[1]

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In most areas of eastern North America the current strategy for controlling damage by the eastern spruce budworm is tree protection. As forest utilization becomes more intensive, alternative strategies involving the prevention of outbreaks may become feasible. The synthetic sex attractant (fulure) could play a role in the detection of incipient outbreaks (sex attractant traps) and in their suppression (mating disruption). The growth of an outbreak depends on the dispersal of egg-bearing females, which takes place only at high population densities. Knowledge of what triggers dispersal is therefore important in planning a strategy of outbreak prevention.

The common name, spruce budworm, has been applied in the past to several species of the genus *Choristoneura,* native to North America, that feed on the new shoots of conifers. Of these the eastern spruce budworm, *C. fumiferana* (CLEM.) has the widest distribution and, at least in Canada, is economically the most important and it is this species which will be discussed here.

The eggs hatch in late July and August and, with no feeding, the larvae spin hibernacula in crevices on the branches of the host conifers where they remain over winter. In the following April or May the larvae emerge and after a brief spell of needle mining feed on expanding shoots of the host trees, principally balsam fir, white spruce and, in its restricted range in eastern North America, red spruce. The larvae pupate on the foliage in July and the adults emerge some two weeks later. As is general among Lepidoptera, the virgin female releases a sex pheromone which is used by the male to locate the female (SANDERS & LUCUIK, 1972).

For long periods the eastern spruce budworm is a minor component of the complex of defoliators feeding on balsam fir and spruce. However, unlike most of its associates, it periodically erupts into extensive outbreaks which spread throughout most of the range of the host plants, killing many trees. The economic impact of the eastern spruce budworm increases from west to east of its range, as the balsam fir component of the forest, the most vulnerable tree, increases. Thus, the problem is most severe in eastern Quebec and New Brunswick where more than half of the forest is comprised of balsam fir. As the forests become more intensively utilized in the future so the budworm will become a more severe problem throughout its range.

The current strategy for managing the budworm problem is largely one of tree protection. Annual assessments are made and when trees needed by industry are in danger of being killed by the budworm, they are sprayed with insecticides to kill sufficient budworm larvae to allow the trees to survive until the following year,

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when another assessment is made. Using this strategy millions of hectares in eastern Canada and the State of Maine have been sprayed over the past 25 years.

Strategies aimed at suppressing an outbreak when it is well established are not feasible. First, to achieve the level of mortality which would have to be inflicted on the budworm population (in excess of 95%) throughout the whole outbreak area would be impractical. Second, any treatment that does not cover the whole outbreak area (which may extend for tens of millions of hectares across provincial and international boundaries) is bound to fail because of the migration of egg-bearing female moths. Recent studies of budworm dispersal in New Brunswick (GREENBANK *et al.*, in press), centered around the use of radar to track the flying insects involving entomologists and meteorologists from several countries, have shown that at high population densities most female budworm migrate, carrying with them a large proportion of their egg complement. Arrival of these migrants can reinfest an area even if the resident outbreak population has been virtually eradicated.

An alternative strategy is to detect and suppress incipient infestations before they start to spread. At relatively low densities it is theoretically possible, with only modest levels of mortality, to suppress the population to a density which can again be regulated by the budworm's natural enemies. The biggest problem in the implementation of such a strategy lies in monitoring population fluctuations at low densities and detecting threatening population increases. Conventional sampling techniques become impractical at densities below one larva per branch of the host trees, but this is about the critical population density where the budworm escapes regulation by its natural enemies. Traps baited with the synthetic sex attractant, a blend of *trans*- and *cis*-11-tetradecenal (SANDERS & WEATHERSTON, 1976), offer a potential alternative - they are capable of catching significant numbers of males at population densities well below one larva per branch, and they are relatively cheap, quick and easy to use, making them suitable for extensive use (SANDERS, 1977). But, before the traps can provide the information required, the catches must be correlated with population density. Since this necessitates extensive sampling of low density populations, it will require considerable effort and will take time.

Such a strategy of outbreak prevention should involve smaller areas than the current extensive protection programs. This would allow the use of environmentally more acceptable, but much more expensive, alternatives, among which would be included the use of the synthetic attractant to disrupt mating behavior. Several field trials have been carried out to develop and evaluate the synthetic attractant for disruption. In 1975, 12 ha in Ontario were sprayed by aircraft with microcapsules containing the synthetic attractant (fulure) (SANDERS, 1976). In 1977 and 1978 larger areas, up to 250 ha, in Ontario, New Brunswick and Nova Scotia were sprayed using hollow fibres containing fulure. The fibres, being larger than the microcapsules are easier to locate and measure for the assessment of deposit and release of the attractant. All trials resulted in big reductions (up to 99%) in the numbers of males caught in traps baited with virgin females. However, attempts to demonstrate significant reductions in the density of the next generation were confounded by late application of the attractant, by collapsing budworm populations, or by invasion of the test plots by egg-bearing females from elsewhere.

Thus once again we are faced with the problem of the dispersal of female budworm, which will now be discussed in more detail. The sequence of events in the first 4 days of the life of a female spruce budworm as determined by laboratory

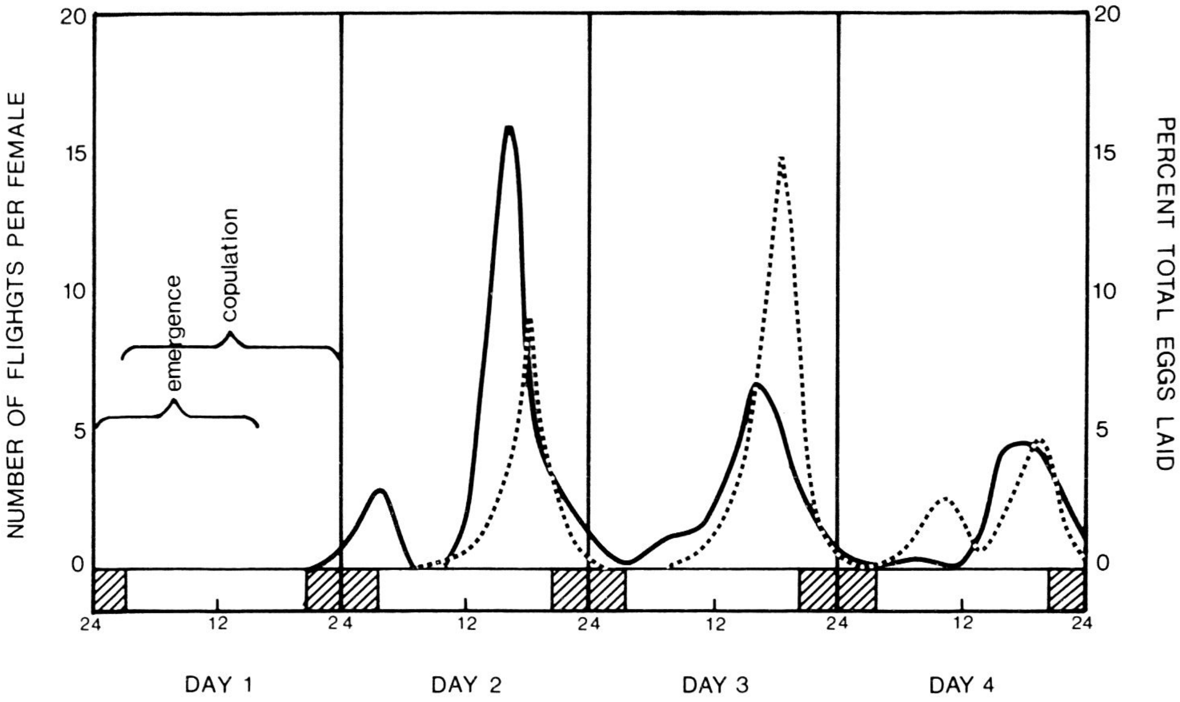

Fig. 1: Summary of female eastern spruce budworm flight and oviposition activity in the laboratory (from SANDERS and LUCUIK 1975). Solid line - percent of eggs laid; dotted line - flights per female.

experiments is summarized in fig. 1. After emergence the female remains sedentary. At high population densities, which are simulated by the conditions in the laboratory, most females are mated during the afternoon on the day of emergence. For instance, SMITH (1954) recorded the peak number of copulating pairs in an outbreak at approximately 17.00 hrs. Allowing for a copulation period of 3–4 hours (SANDERS 1975), copulation in the field would then be terminated by 20.00. The first spell of oviposition in the laboratory peaks at about 20 hrs after the end of copulation (SANDERS and LUCUIK unpublished) i.e. at 16.00 hrs on the day following emergence. This is corroborated by the laboratory data in fig. 1. At this time approximately 50% of the total number of eggs laid would have been deposited. Flight activity however, does not peak until later, 18.00 in the laboratory, somewhat later under field conditions. Thus, on the average a female lays 50% of her eggs during the afternoon of day 2, and then flies. On day 3, a further 25% of her eggs are laid, followed by flight and the pattern continues on successive days. This corroborates field investigations (GREENBANK *et al.,* in press) which concluded that the dispersing females are 2 or 3 days old and carry between one-third and one-half of their egg complement.

However, dispersal does not occur under all conditions. In 1976 observations were made on spruce budworm dispersal in four different locations in Ontario (tabl. 1). Where populations were of moderate density (Searchmont, tabl. 1) and the trees were moderately or severely defoliated for several years, large numbers of females were seen dispersing out of the stand. However, in the three other observation areas where populations were of low to moderate density and defoliation had been light in previous years, no dispersal was seen even though conditions were favorable on several evenings. The conclusion therefore is that dispersal does not occur at low to moderate population densities from stands showing little or no defoliation.

Table 1: Population densities and defoliation estimates in 4 forest stands in Ontario where observations were made on the dispersal of female eastern spruce budworm in 1976.

Location	Budworm populations /45 cm branch tip		Defoliation history (% new foliage eaten)				Dispersal
	Larvae	Pupae	'73	'74	'75	'76	1976
Searchmont	17	1.5	M-S†	M-S†	80	24	++
Manitouwadge	13	0.4	10	6	38	47	0
Aldina	-*	0.5	0	1	10	47	0
Black Sturgeon Lake	0.8	0.01	0	1	4	1	0

* Not sampled. †M-S = moderate to severe.

Predicting when, in the development of an outbreak, dispersal will first occur is of critical importance in implementing a strategy of population prevention. Increasing population densities are of no consequence in stands or areas which are of no commercial value, up until the time when dispersal occurs from these stands and threatens to infest other stands which are of value. Thus, a critical question is what factor triggers dispersal. It could be a direct density dependent effect such as interaction among the larvae, or competition for oviposition sites, possibly it is a feedback mechanism through the host plant. Another possibility is that the females are reacting to their own pheromone. It has been shown in the laboratory that the level of female budworm activity is increased in the presence of high concentrations of the pheromone (Seabrook pers. comm.). This is an intriguing possibility which deserves further investigation, in the field higher concentrations of pheromone could lead to more dispersal. Not only would this be of significance in determining at what population densities the females disperse, it would also be of significance in the effects on female behavior of permeating the atmosphere with artificially high concentrations of pheromone in attempts to disrupt male orientation.

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