SEX AND THE SINGLE GYPSY MOTH
OR
MATING DISRUPTION FOR GYPSY MOTH POPULATION MANIPULATION

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INTRODUCTION

The title I have used for this talk, "Sex and the Single Gypsy Moth, or, Mating Disruption for Gypsy Moth Population Manipulation," conveys a couple of ideas. The gypsy moth, a major insect pest of northeastern hardwood forests, does its damage as populations of insects. It is these populations which must be manipulated if the insect is to be controlled. But populations are composed of individuals. A behavioral chemical, such as disparlure, the synthetic attractant of the gypsy moth, affects actions of those individuals. And I do not have to remind a group of biologists of the variability which is associated with individuals in a population.

During the next few minutes, I propose to do several things: I will review briefly the history of gypsy moth pheromone work, outline some of the potential uses that have been suggested or advocated for disparlure, and assess the current state of the art as I see it.

Forbush and Fernald (1896) were aware that the gypsy moth female, normally flightless, produced a material which attracted males for mating. In 1960, Jacobson et al. identified gyptol as the sex attractant; Jacobson (1960) reported that gyplure, an easily-synthesized homologue, was also a potent attractant. During the next few years, many tests of these materials gave erratic and unpredictable results. Eiter et al. (1967) finally challenged the validity of the chemical determination, and Jacobson et al. (1970) eventually retracted the earlier work. Meanwhile, another team pursued identification of the material, culminating with a report in 1970 by Bierl et al. of the isolation, identification, and synthesis of disparlure, a potent attractant of the gypsy moth. The material is rather easily synthesized, and in large quantities. For example, this year (1975) approximately 1,500 pounds were purchased at a cost of less than $100/1b.

For several years now, I have questioned whether or not disparlure is the only chemical component of the gypsy moth pheromone system which governs the behavioral sequence of events during which a male and female moth perceive each other, come together, and mate (Cameron, 1973). Thus far, I am unaware of any literature reports giving evidence that an additional compound or compounds is/are involved in this system. But in view of the complexities of systems for most other insects, and especially moths, I believe the question must remain open. It should be obvious that, should more compounds be found for the gypsy moth, the role of chemical ecology in gypsy moth pest management would be in need of reassessment,

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Beroza (1967) and Carde et al. (1973) have reported the presence of an agent which inhibited or masked response to the sex attractant, The material has been identified as an olefin precursor of disparlure. Limited field testing of this material in 1973 did not encourage pursuit of the suggestion that this material, rather than disparlure, would be effective in disrupting chemical communication between, and ultimately mating of, gypsy moths (Cameron et al„ 1975). But again, this avenue has not been fully explored,

Recently, Hendry and colleagues (1975) have reported finding compounds identified as sex attractant pheromones of a number of phytophagous insects in a variety of host plants. Most of their reported work has dealt with the oak leafroller, another serious pest of oak forests, but they suggest that many insects may, indeed, obtain at least part of their pheromone complement from their food plants. If their theories are correct, some novel approaches to insect control may be developed.

For several years now, the U, S. Forest Service has had Cooperative Agreement money with a group in Ohio to investigate the chemistry of nonpreferred food plants of the gypsy moth, It has long been known that ashes (*Fraxinus* spp.) and tulip-poplar (*Liriodendron tulipifera*) are not gypsy moth hosts, While details have not been published, there are indications that both feeding repellents and lack of phagostimulants may be implicated.

So much for a brief overview of gypsy moth pheromones and related chemistry, Now let us come back to disparlure and assess the current state of the art for the several roles which it may play in gypsy moth population management programs.

FIRST, there is the classical role of survey and detection. For years, females, extracts of females, and, more recently, disparlure have been used in a wide variety of traps to monitor the spread of this pest throughout many parts of the United States and Canada. Used in this way, the chemical plays an early warning role in pest management: while the role may be only qualitative and not truly quantitative, it is important.

A SECOND role for disparlure is suggested by the mention of numbers. It is one thing to catch a moth or moths in a trap, and quite another to know what this means in terms of the gypsy moth population. If we had some way of measuring or, even more desirably, of predicting population levels based on trap catches of male adults, we would have a very valuable tool. Preliminary work along this line has been reported by Granett (1974), but the development of this role for disparlure still needs much work,

Far and away the greatest sums of money have been spent, and are likely to continue to be spent, on trying to establish a THIRD role for disparlure: its use directly in manipulation of gypsy moth populations. Indeed, in one version of the expanded gypsy moth project, almost 25% of the total funds (which exceeded $20 million) were earmarked for developing and testing this material, Only about 10-15% of the disparlure monies were to be directed to the more basic studies of such areas as adult behavior and a determination of optimum and maximum population levels for treatment (a serious misstatement of priorities, in my opinion). The bulk of the expenditures would be for large-scale field tests which, hopefully, would bring disparlure on-line as another in the arsenal of weapons with which to fight our nemesis, One way or another, the goal is essentially a broadcast application of the lure.

For what goals, or in what manner, might such broadcast applications be used? Let us consider several.

Each year, survey and detection efforts locate gypsy moths in areas remote from known infestations. Sometimes these incipient infestations are very localized; at other times they may cover thousands or tens of thousands of hectares. Elimination, or eradication, of populations from these isolated infestations in remote areas is, in some cases, a reasonable and legitimate goal. How? And what is the current status of appropriate tests involving disparlure?

During the period 1971-1973, our group was working in an isolated infestation in southwestern Pennsylvania. During the first two years, baited traps were aerially dropped at rates of up to 8400/km^2 over an area of up to 35 km^2 (Cameron, 1973). For a number of reasons, we were unable to hold the population in the area static, let alone reduce it. In 1973, we treated the area with a broadcast application of the recently-developed and promising microencapsulated formulation of disparlure. Unidentified factors caused substantial population reduction during the larval stage, but we believe that the treatment had a measurable disruptive effect on successful adult mating. Funding priorities established in Washington for the limited available dollars precluded the continuation of this test past 1973.

Testing has been done by others on islands isolated from surrounding infestations by water barriers, and a sizeable test was run in Michigan in 1974 in a part of the almost 280,000 hectares estimated to be infested. While some interpret results in these tests to be promising, we still lack proof that disparlure, alone or in combination with other population suppression agents, can eradicate the gypsy moth from a localized area. I might add, as a footnote, that one seldom hears talk today of eradicating the gypsy moth from North America. And that is as it should be.

A second manner in which broadcast application of disparlure might be used in gypsy moth pest management is through the establishment of a barrier zone. It is not my intention or desire to argue the merits or disadvantages of a barrier zone per se--and there are strong arguments on both sides of that question. Rather, I would raise for consideration some of the elements to be considered if a barrier zone is to be effective. (Parenthetically, a barrier using disparlure would, of necessity, be directed against natural spread of the insect; I can envision virtually no role for this material in a barrier against the man-associated spread of the moth.)

To guide the selection of the barrier area, we should know the maximum adult population densities in which disparlure will essentially totally disrupt mating. (This we don't know yet). We should know how far larvae drift during their wind-borne dispersal phase. (Theoretical models are under development, and limited field testing has been initiated, Many answers remain to be obtained.) We must have extensive and probably intensive survey and detection networks in the area of the barrier to identify potential trouble spots or sources from which populations may spread. We are likely to need chemical insecticide treatments over large areas (tens or hundreds of thousands of hectares) to reduce the pressure on the barrier zone arising from the generally infested area, and possibly within the barrier itself. We will need large quantities of lure in a suitably persistent formulation that can be applied early enough to affect the early-emerging males, and yet remain active until the end of the flight season. And we will need the capability of monitoring within the barrier to demonstrate that a barrier has, in fact, been established, i.e., no infestations are persisting or becoming established within the designated zone.

Until we have these kinds of capabilities and answers, I believe that an attempt to establish a barrier is premature. Unfortunately, we are still begging answers to virtually every question I raised. Therefore, I cannot believe that we are ready to initiate a barrier zone approach.

A third role for broadcast applications of disparlure is use in areas of chronic or well-established infestations. Here we might be dealing with extensive forested areas or smaller urban or suburban situations.

It is generally agreed that disparlure alone, whether in traps or in broadcast applications, is incapable of having much effect on populations except when they are at a very low (and as yet undefined) level. Thus, use of the lure in chronic infestations presupposes population reduction through one or more other agents, such as chemical or microbial insecticides, parasitoids, mechanical removal (e.g., by scraping egg masses or banding trees in a suburban area), naturally occurring factors, etc. Such testing was carried out, both by our own group and by others in 1974. Our experience, in rather extensive trials, does not persuade us that we are able to do a better job with one or other of the registered insecticides followed by disparlure treatments directed against surviving adults, than with a carefully timed application of the insecticide alone.

If you have been listening so far, you may feel that I am pessimistic about the role of disparlure in gypsy moth pest management. I have said that this chemical is useful and <u>operational</u> for survey detection, but is not ready foroperational--and I stress operational--use in other contexts: population monitoring and/or prediction, eradication of isolated infestations, the establishment of a barrier zone, or use in a chronic infestation.

There are steps that are being or should be taken to try to make our great theories operational realities.

Very few formulations of the lure have been tested; several of these have given encouraging results in field tests, With the recent commitment by ARS of a chemist competent in the area of formulations to the program, we can expect progress in this area. Field testing, of course, poses very real problems in terms of time, logistics, and finances.

At the crux of the whole disparlure program is the question of just what is the role of disparlure in mediating gypsy moth behavior, and how does it act? Many times I have said that we are trying to manipulate behavior, but we know precious little about this behavior. For example, how important is disparlure in mate perception and location, and in the mating act? Do other cues, such as the visual, play significant roles? If so, can they be overridden? How important are diet periodicities of pheromone release (identified by Richerson and Cameron, 1974) and male responsiveness? What are the normal search patterns exhibited by males, and can these be altered or terminated? How frequently do males and females mate in nature, and with what results? What are the effects of age on mating propensity and/or success? Over what distances do males respond to a pheromone source?

We have a few of the answers, but many more are needed, Our studies (Richerson et al., 1975b) have shown, for example, that under the conditions prevailing in a dense population, all females, whether virgin or mated, are in effect equally attractive to males. The presence of pheromone does appear to be a prerequisite to initiating sexual activity, We have concluded that males in dense populations do not orient to specific pheromone sources over distances greater than 25-30 cm. Rather, they are stimulated to orient initially to vertical silhouettes such as trees (use of a visual cue) after excitation by the pheromone. At this stage, they mush utilize other stimuli (chemical? visual?) to pinpoint the location of the female.

In sparse populations, males are probably capable of following pheromone-laden air currents directly to a pheromone source, Other stimuli, although perceived, probably play a minor role in mate location. Thus, we have suggested that in sparse populations, the anemotactic response of males to pheromone stimulation is a reliable orienting mechanism to locate females, while in dense populations the most efficient response is to orient to trees where females are most likely to be found (Richerson et al. 1975a, b).

When disparlure is applied to sparse populations we produce a pheromone level indicative of a dense population. Males in the treated area should be stimulated to utilize a behavioral response that is inefficient in areas with few females. If the population is very low, it is unlikely that males will locate females by searching every tree. It is in this density range that the potential use of synthetic pheromones to alter behavior and disrupt mating is most promising. As the density of moths increases, the probability increases that a pheromonally stimulated male will finally locate and mate with a female, Therefore, at high population densities, mating disruption programs using disparlure have little chance of success.

As we continue to test hypotheses such as these from a behavioral point of view, we find over and over that the gypsy moth does not act as a nice little robot, but is quite adaptable to different sensory situations. We still don't understand all that happens in the chemical communication system--or other sensory systems for that matter--so we continue to look for critical links in the behavioral chain. Only in this way will we have a better chance to effectively utilize behavioral chemicals for gypsy moth mating disruption and population manipulation.

In the five years since Bierl et al. (1970) announced the isolation, identification and synthesis of disparlure, great progress has been made in understanding many more facets of gypsy moth adult behavior, and much time, effort, and money has been spent in attempting to use this new generation material in field control programs. Survey and detection efforts have greatly improved; steps towards developing monitoring and prediction capabilities have been taken. Disparlure may yet become operational in other contexts, but we remain at a place where, as said in 1972, 'Disparlure is a potential tool for gypsy moth population manipulation: We still have not been able to determine how to utilize its potential effectively.' (Cameron, 1973).

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