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MATING SUCCESS OF GYPSY MOTH (LEPIDOPTERA: LYMANTRIIDAE) FEMALES IN SOUTHERN WISCONSIN

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ABSTRACT

Mating success of laboratory-reared gypsy moth *Lymantria dispar* (L.) females exposed for 24 hr on tree boles and its relationship to male moth counts in pheromone-baited traps was studied in southern Wisconsin. The relationship between mating probability of gypsy moth females and male moth counts in traps corresponded to an exponential model that can be used for predicting mating probabilities in sparse isolated populations. Relative attractiveness of females compared with traps was 0.23, which is similar to earlier estimated relative attractiveness of females in Virginia. The mortality of females from predation, however, was found to be significantly lower in Wisconsin than in Virginia, which may contribute to a larger degree of mating success. Increased long-distance dispersal of males could also contribute to the increased mating success of females. The higher rate of spread of gypsy moth populations in Wisconsin compared with other areas may be due to the increased mating success caused by the lower female mortality and higher long-distance dispersal of males.

INTRODUCTION

The gypsy moth, *Lymantria dispar* (Linnaeus), is a pest of hardwood forests. The insect was introduced accidentally into the United States near Boston, Massachusetts from France (Liebhold et al. 1989) and has spread at a rate of approximately 20 km/yr to the south, west and north from where it was introduced (Liebhold et al. 1992). In 1993 USDA Forest Service initiated the gypsy moth management program. An objective of the program is to slow the spread of the insect by suppressing solitary low-density populations (McFadden and McManus 1991, Leonard and Sharov 1995), which establish beyond the population front, grow, and contribute to the main population and to the movement of the front (Sharov et al. 1998).

Very few studies have been devoted to understanding the population dynamics mechanisms specific to low-density gypsy moth populations. One such mechanism is mating success of females, which appears to be a critical inverse density-dependent factor (Sharov et al. 1995). Mating success depends mainly on the local abundance of adult males and is correlated highly with the rate of male moth capture in pheromone traps (Sharov et al. 1995). Mating success, therefore, can be predicted from male moth capture in pheromone-baited traps. Sharov et al. (1995) used this approach to study the mating success of gypsy moths in the Appalachian Mountains, Virginia. Another important factor that affects low-density gypsy moth populations is predation, e.g., bird predation on adult males. However, ants were shown to be the most important predators of adult gypsy moth females (Sharov et al. 1995). Ant predators decrease the mating probability of females by decreasing their longevity.

The male moth catches in pheromone-baited traps in Wisconsin range from <1 in the Western and middle part of the state to 30 – 300 in the East (Fig. 1). The spread of gypsy moth populations in southern Wisconsin also occurs much faster than in the Appalachian Mountains, Virginia (Sharov 1998). It has been hypothesized that this difference in the rate of spread between the two regions may be due to the higher mating success of females and subsequent higher rate of growth in low-density populations in Wisconsin (Sharov et al. 1999). In contrast to the Appalachian Mountains, male moth counts in pheromone traps in Wisconsin

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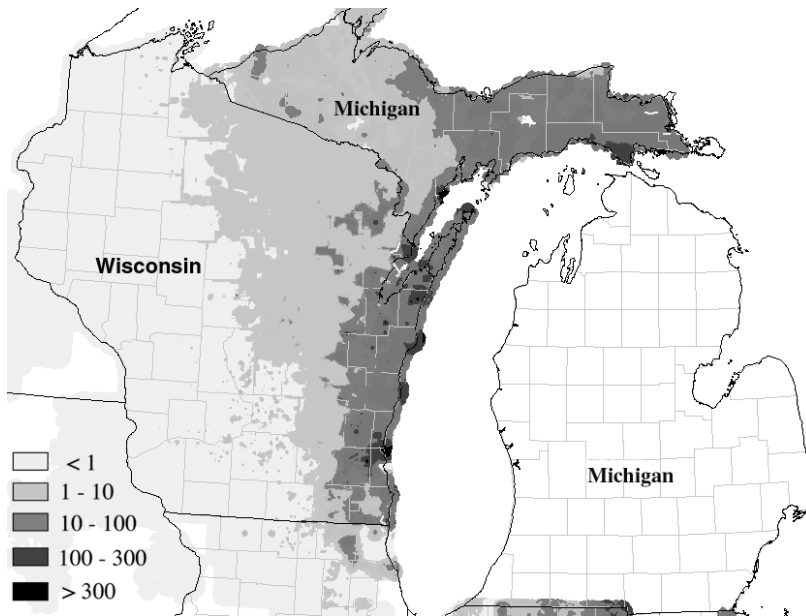
Fig. 1. Male gypsy moth counts in traps in Wisconsin, 1999

tend to decrease more gradually with increasing distance from the population front (Régniére and Sharov 1998). This suggests that male moth dispersal may be more extensive in Wisconsin than in the Appalachian Mountains. In this paper we describe the study of the relationship between mating success of gypsy moth females and male moth captures in pheromone traps. In order to understand the mechanism of mating success of gypsy moth females in Wisconsin, we compared this mechanism with the mating success observed in the study done previously by Sharov et al. (1995) in the Appalachian Mountains, Virginia.

MATERIALS AND METHODS

A study was conducted in Kettle Moraine State Forest and nearby forested sites in Wisconsin between July 25 and August 6, 2000. Based on male moth catches in pheromone-baited traps (Fig. 1), seven study plots were established at various distances from an advancing gypsy moth front (Fig. 2). Three plots were located in Waukesha County and four plots in Walworth County.

Mating success of gypsy moth females was evaluated using tethered virgin females. Gypsy moth females were raised from pupae obtained from USDA-APHIS Otis Methods Development Center (Otis, MA). Virgin 1-day old females were tethered by a 10-15 cm thread tied to the base of the front wing and attached to a tree by a pushpin (Sharov et al. 1995). Two lines of 10-13 tethered females per line were established in each plot. The lines were separated by a distance of 20 m, and the distance between females in a line was 20-25 m (Fig. 3). A barrier of tanglefoot glue was applied in the radius of 25 cm around females in some of the plots to protect individuals from natural predators (e.g., ants). Females were left on trees for 24 hr, after which they were removed and their fertilization status was determined via dissection. In some plots, where male trap catches were = 0.5 males per trap, females were left on trees for two days. Females that were collected were stored in the vials for 24 hours and then dissected to check for the presence of sperm in the spermatheca. Egg masses also
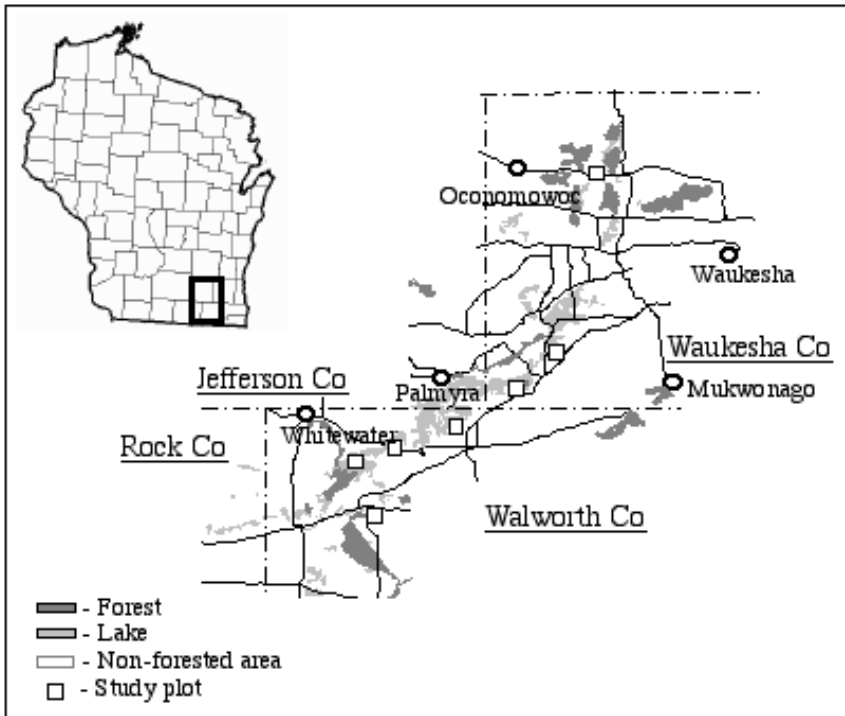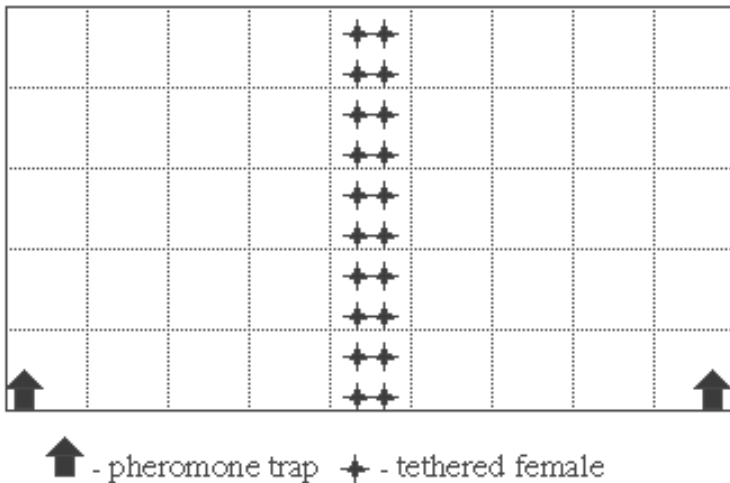
Fig. 2. Map of experimental plots in Wisconsin

Fig. 3. A study plot in Wisconsin showing the layout of tethered gypsy moth females and pheromone-baited traps.

were analyzed for embryonation in those cases where we were uncertain about whether mating had occurred. Non-fertilized eggs do not develop but remain white, whereas, fertilized eggs become dark and a larva can be observed inside the egg under a dissecting microscope.

Male moth abundance was determined using pheromone-baited traps (Fig. 3). Two pheromone-baited traps were placed in each plot at a distance of 100 m from the lines of females to avoid competition between the two pheromone sources (Fig. 3). Larger distances could not be used because of the fragmented forest landscape. The pheromone traps were checked before placing tethered females on trees and at the time females were collected.

The relationship between mating success of females and male moth capture was described by the exponential model (Sharov et al. 1995):

$$P(t) = 1 - \exp(-s \times t \times M) \qquad (1),$$

where $P(t)$ is the proportion of females that are mated during time t (days), M is the male catch per trap per day, and s is a parameter that can be interpreted as the relative attractiveness of virgin females to males compared with pheromone-baited traps. The parameter s was estimated using nonlinear regression of $P(t)$ versus $(t \times M)$ (least squares method). The fit of the model was checked using the coefficient of determination (R^2).

Predation rate on gypsy moth females in Wisconsin was estimated by counting the proportion of females removed by predators per day among individuals not protected with a tanglefoot glue barrier. A Chi-square (χ^2) test was used to compare the mortality of gypsy moth females in Wisconsin with that in Virginia using the data collected by Sharov in 1995 (Sharov et al. 1995).

RESULTS

The average trap capture rate in the study plots in Wisconsin, ranged from 0.1 to 42.5 male moths per trap per day; the mating probability of gypsy moth females ranged from 0 to 0.95 (Fig. 4). Mating success of females increased with increasing male moth captures in traps. The relative attractiveness of females compared with pheromone traps, $s,$ was 0.23 with a 95% confidence interval of 0.16 to 0.30 $(R^2 = 0.816)$.

In Wisconsin, the mortality of gypsy moth females from predation ranged between 0 to 35% per plot per day (Table 1) with an average of $14.2 \pm 2.5\%$.

DISCUSSION

This first study of gypsy moth mating success in Wisconsin indicates that the mating probability of females can be predicted from male moth capture in pheromone traps. This may be important for determining the extent to which moth captures are associated with stable reproducing isolated colonies of the gypsy moth in the areas beyond the expanding population front. The threshold number of male moths captured per season that is associated with a stable population was determined using the model (Sharov et al 1995):

$$1 - \exp(-s \times t \times M) = \exp(-r) \qquad (2),$$

where s is the parameter that describes the relative attractiveness of virgin females to males compared with pheromone-baited traps, t is female calling time (days), and M is male moth catch per trap per season. The calling time t of females depends on the dynamics of pheromone emission but also may be reduced by predation. Females are usually attractive during the first three days of their lives, and thereafter their attractiveness declines sharply (Collins and Potts 1932, Richerson and Cameron 1974). Considering the predation rate of 14.2% per day as the only mortality cause, the average survival time of females in Wisconsin would be $-1/\ln(1-0.142) = 6.53$ days. This time is longer than the
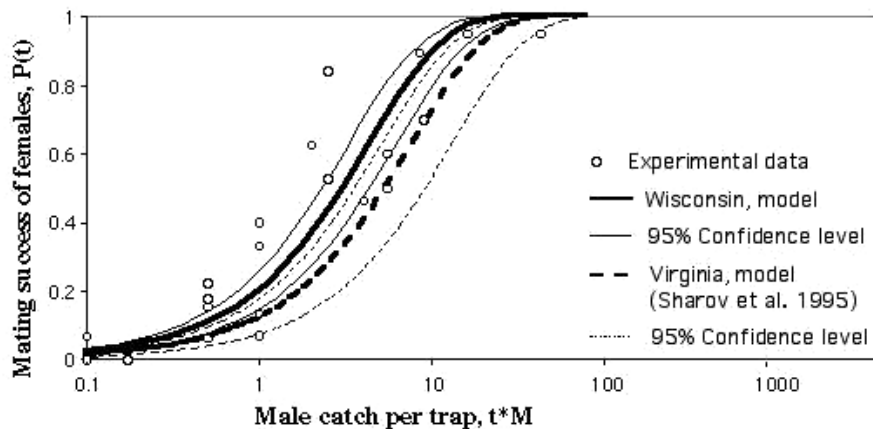
Fig. 4. Mating probability of gypsy moth females and males captured in pheromone-baited traps.

Table 1. Mortality of gypsy moth females in Wisconsin

Date	Plot #	Females analyzed	% Mortality
29-Jul-00	13	20	4.8
31-Jul-00	1	20	0
31-Jul-00	2	20	0
31-Jul-00	4	23	4.2
01-Aug-00	16	13	35
02-Aug-00	12	13	35
02-Aug-00	16	15	25
03-Aug-00	12	16	20
03-Aug-00	14	17	15
04-Aug-00	1	20	0
04-Aug-00	12	19	5
04-Aug-00	13	19	4.8
04-Aug-00	14	16	20
05-Aug-00	12	20	0
05-Aug-00	14	15	25
05-Aug-00	16	14	30
06-Aug-00	1	20	0
06-Aug-00	2	18	10
06-Aug-00	4	18	10
06-Aug-00	13	19	9.5
06-Aug-00	14	17	15
06-Aug-00	16	15	25

calling time (3 days). Thus, predation does not appear to limit female calling time in Wisconsin.

The threshold number of males associated with a stable population, *M*, was also calculated using average population growth rate $r = 1.65$ (Sharov et al. 1995). This yielded $M = 0.23$ males per day. Assuming a 3-week average flight period, this is equivalent to 4.8 males/trap/season. Thus, male moth catches below 5 moths per trap are usually not associated with a reproducing population in this particular location. However, for monitoring purposes, a catch of 5 moths per trap may be an indication of a reproducing population that is located at some distance from the trap (e.g., 1-2 km away).

The results of the study of the mating success of gypsy moth and male moth capture in the pheromone-baited traps in Wisconsin were compared with the results of an analogous study conducted in Appalachian Mountains, Virginia. In the study in Virginia, *s* was estimated as 0.15 with a 95% confidence interval of 0.09 - 0.23 (Sharov et. al 1995). The confidence intervals of *s* in Wisconsin and in Virginia overlap (Fig. 4), suggesting that there is no significant difference in the relationships of mating success of gypsy moth females and male moth counts in traps in the two regions. Female mortality from predation in Virginia ranged from 30 to 94% per day with an average predation of $52 \pm 5\%$. Mortality of gypsy moth females from predation, therefore, was significantly lower in Wisconsin than in Virginia ($p < 0.001$). The threshold number of males associated with a stable population, *M*, was estimated to be lower in Wisconsin ($M = 4.8$ males/trap/season) than in Virginia ($M = 7$ and 15 males/trap/season with and without predation respectively). Therefore, the rate of population spread in Wisconsin is higher than in Virginia.

In the study in Virginia, predation considerably reduced the waiting time of females $t = 1.36$ days compared to Wisconsin, where $t = 6.53$ days (Sharov et al. 1995). This suggests that females live longer and have a higher chance of mating in Wisconsin than in Virginia.

In the light of the above discussion we may conclude, that the higher rate of population spread in southern Wisconsin compared with the Appalachian Mountains, Virginia may be due to the increased mating success of females, which is probably caused by the increased long-distance dispersal of males and the longevity of females.

ACKNOWLEDGEMENTS

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