Gypsy Moth Female (*Lymantria dispar* L.) Flight Potential in Lithuania

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Flight before copulation was found in the behavior of 17.3% females with normal mating and of 50.0% with mating delayed for 3 days; walking - respectively in 55.8% and 19.1%, no movement - in 26.9% and 30.9% cases. After mating 30.0% and 37.3% females (normal and delayed mating) were flying, 40.0% and 25.5% walking, 30.0% and 37.3% started egg laying at the place of mating. Female take off before mating occurred in 37.3-58.0% cases on surfaces with 70°, 100°, 130° and 180° (upside down) inclination; walking was recorded with significantly lower frequency in upside down position (20.6%) compared to other positions (54.9-37.1%); significantly more females were staying intact upside down (26.5%) than on other locations (2.3-7.8%). Flight after mating was significantly more frequent to females on 70° slope (53.8%), compared to other locations (21.1-34.3%); egg laying without moving was recorded in 42.1-48.6% cases on all surfaces, except with 70° inclination (5.1%).

Key words: gypsy moth, *Lymantria dispar*, female, flight.

Introduction

Gypsy moth (*Lymantria dispar* L.) is one of the most serious defoliating forest pests, forming extensive and devastating outbreaks in cool temperate Holarctic regions. It was introduced in North America from Europe in late the 1860's and despite all control and eradication efforts has persisted and expanded its range (Wallner 1989). Although there are indications of flying gypsy moth females in Europe and America (Gornostajev 1962, Sandquist et al. 1973), the assumption that the females of European form are flightless is widely accepted, and entomologists have been ignoring and discounting these single and exceptional reports.

In Lithuania evidence of possible gypsy moth female flight was discovered in 1995, when a lot of females were found on the sandy beach along the Baltic Sea cost. Another indirect sign of female displacement was an outbreak, started without any evident reason in the isolated location with no previous gypsy moth damage records. In recent years some more information was reported (Bogenshutz 1994, Keena et al. 1996, Reineke and Zebitz 1998), forcing me to presume that female flight and migration may not be so exceptional phenomenon as believed earlier. So far we have very limited and scattered data on this subject, therefore our observations were made to reveal and quantify flight potential in female gypsy moth in Lithuania in relation to male waiting time and inclination of surface on which females were staying.

Material and methods

Gypsy moth were collected as pupae in birch (*Betula pendula* Roth., *B. pubescens* Ehrh.) and mixed birch and alder (*Alnus glutinosa* Gaerth, *A. incana* Dc.) forests. In 1995 and 1996 pupae were collected near Nida, in narrow sandy spit along western coast of Lithuania, in the area of collapsing outbreak with peak defoliation in 1993. Previous gypsy moth outbreaks in that area were recorded in 1971-75 and 1982-83. Interestingly, gypsy moth outbreaks in Lithuania have been recorded only in Nida's area at least over the past 60 years. In 1997 material was collected in Silute county (Fig. 1), about 40 km west-southwest from Nida.

Pupae, collected in field, were kept in the laboratory to eclosion. To quantify flight potential in relation to male waiting time females after emergence were

Figure 1. Location of gypsy moth outbreaks (dashed area) in Lithuania.

placed on vertical mesh screen in the laboratory, one group allowed to mate without hindering (free flying males present immediately), another - with males present only on the third day after eclosion.

To find out the most preferred inclination of surface for mating and egg laying and its impact on flight behavior, females were placed on the inner surface of cylindrical mesh screen with 2 m radius at the positions having 70°, 100°, 150° and 180° (upside down) slope to horizon (Fig. 2). Copulation was allowed on the next day, and mated females again were placed at the same positions. Female position after copulation was chosen randomly, without taking into account its former placement.

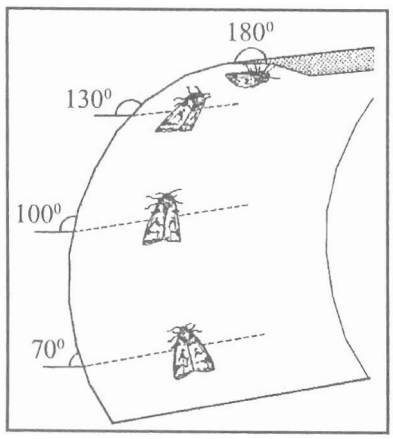

Figure 2. Design of experiment: females (drawn not to scale) were tested on the inner surface of open half-cylinder with radius of 2 m.

Female behavior was recorded prior to mating and after mating, distinguishing three types of behavior in each phase: 1) inert - females that has not moved more than about 10 cm from initial location; 2) walking - females were walking; 3) flying - females exhibited sustained flight pattern. Every female was tested only once, and only one behavioral event was recorded for every female in each of two intervals: from eclosion to mating and from mating to oviposition (Fig. 3). "Flying" behavior had priority over "walking", i.e. females that have been noticed to take off after walking were recorded as flying only.

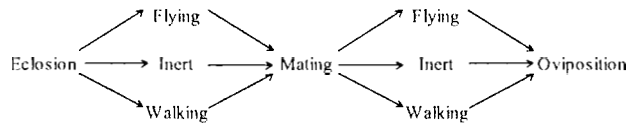

Figure 3. Gypsy moth female behaviour.

Statistics (mean and variance) were calculated using methods for qualitative variations and results were compared using Chi-statistics (Lakin 1980)

Results

Total number of 52 moths were tested normally mated and 68 with male waiting for 3 days after eclosion. However, some tested individuals were lost flying before mating (12 and 17) and second observation phase - behavior after mating - entered 40 and 51 females, for both test series respectively.

About one third of females have not moved notably from the place of emergence before mating, and there was no significant difference in cases with regular (26.9%, Table 1) and delayed copulation possibility (30.9%). 17.3% of females exhibited flight in the undisturbed mating and this was significantly less (χ^2=7.232, $p<0.01$) than in delayed mating case (50.0%). On the other hand, there were significantly more walking indi-

Table 1. Behaviour of gypsy moth female in Lithuania.

Behavior	Number of females (count and percent)				Difference
	Normal mating		Late mating (3 days)		
Before mating					
Inert	14	26,9 ± 6,2%	21	30,9 ± 5,6%	n.s.
Walking	29	55,8 ± 6,9%	13	19,1 ± 4,8%	***
Flying	9	17,3 ± 5,2%	34	50,0 ± 6,1%	***
Total:	52		68		
After mating					
Inert	12	30,0 ± 7,2%	19	37,3 ± 6,8%	n.s.
Walking	16	40,0 ± 7,7%	13	25,5 ± 6,1%	n.s.
Flying	12	30,0 ± 7,2%	19	37,3 ± 6,8%	n.s.
Total:	40		51		

*** - difference significant at $p < 0.01$; n.s. - not significant

viduals between unhindered females (55.8%) than between those with copulation withhold (χ^2=5.862, p<0.01). The difference was in part caused by behavior event ranking, as flight was ranked higher over walking, and only one behavior was accounted.

After mating there were no significant differences in the behavior of tested gypsy moth females. Egg laying was started by 30.0 and 37.7% of tested females (normal and delayed mating, respectively, table 1). There were more walking females in routinely mated group (40.0 against 25.5% in late mating case), but difference was insignificant. One third of all tested females (30.0 and 37.3%, mating alternatives, respectively) were found to fly prior to egg laying. If not dividing behavior to pre- and post-mating phases, flight was recorded in the behavior of 22 females (42.3±6.9%) with normal and in 34 females (50.0±6.1%) with postponed mating.

Total number of 323 females entered experiments to reveal the impact of surface inclination at which females were staying to their behavior. Before mating almost all females were moving, but in the group placed on 180° slope, i.e. upside down, 26.5±7.6% the individuals were inert (table 2), and this was significantly different (χ^2=4.538, 5.896 and 9.586, p<0.05) from other locations, were only 2.3-7.8% of females remained at the spot they were placed.

Behavior of total 116 females was recorded after mating. 53.8±8.0% of females, mated on 70° slope, revealed flight and this was under the significant difference limit from other groups (χ^2=1.684, 0.708, 0.784, p>0.1), were only 21.1-34.3% individuals were flying. On the other hand, significantly higher proportion of females remained motionless (42.1-56.5%, table 2) and initiated egg laying, when placed on surfaces with 100-180° slope, if compared to those on 70° slope surface, were only 5.1±3.5% moths put eggs at the place of mating (χ^2=6.100, 9.266, 10.013, p<0.025).

Table 2. Female behaviour on surfaces with different inclination

Surface slope	Percent of females: inert		walking		flying		Total number
			Before mating				
70°	7,8 ±2,7%	a	54,9 ±4,9%	a	37,3 ±4,8%	a	102
100°	2,3 ±2,2%	a	40,9 ±7,4%	ab	56,8 ±7,5%	ab	44
130°	**4,9 ±1,8%**	**a**	**37,1 ±4,0%**	**ab**	**58,0 ±4,1%**	b	143
180°	26,5 ±7,6%	b	20,6 ±6,9%	b	52,9 ±8,6%	ab	34
			After mating				
70°	5,1 ±3,5%	a	41,0 ±7,9%	a	53,8 ±8,0%	a	39
100°	**42,1 ±11,3%**	b	36,8 ±11,1%	**a**	**21,1 ±9,4%**	**a**	19
130°	48,6 ±8,4%	b	17,1 ±6,4%	a	34,3 ±8,0%	a	35
180°	56,5 ±10,3%	b	13,0 ±7,0%	a	30,4 ±9,6%	a	23

Percentage followed by the same letter within columns are not significanly different (χ^2 test, p<0.1)

In Lithuania evidence of possible gypsy moth female flight was discovered in 1995, when a lot of females (no males) were found all way on the beach along the Baltic Sea cost, casted ashore by waves (10-50 females per linear meter of seashore). The nearest pine forest edge was at the distance of 60-80 m from the sea, and separate nearest broadleaf trees within these pine stands could be found only 200 m from the coast line. Another indirect sign of female displacement was a new 2500 ha outbreak, started in 1996 with no evident reason at significant distance, in isolated forest with no previous gypsy moth damage records, having no land connection with former declining and documented outbreak near Nida.

Discussion

Test results clearly show that Lithuanian gypsy moth female population have significant flight potential, which tend to be displayed both by unmated females (in the case males may not be present immediately at the eclosion site), and by copulated individuals prior to oviposition, regardless of mating delay for few days. One third (30.0-37.3%) of Lithuanian gypsy moth females have been found flying after mating, prior to egg-laying. This potential may be even higher, as in our experiments 42.3 and 50.0% females at least once exhibited flight from eclosion to oviposition. Second test series also revealed flight in 37.3-58.0% cases before mating and in 21.1-53.8% cases after copulation prior to egg laying. In Lithuanian population M.Keena (pers. comm.) have found as much as 70% females efficient to fly. Females capable for sustained flight were found in gypsy moth from Lithuania, Poland and Germany in contrast to non-flying Portuguese, French, Austrian, Slovakian, Bulgarian populations (Keena, 1996). This supports geographical female flight capability gradient. Being flightless is definitely distinct characteristics between outlying European and Asian gypsy moth populations (Baranchikov, 1989), intermediate populations should show variable reaction, ranging from entirely flying to completely flightless female in few hundred kilometres (Reineke and Zebitz ,1998)

Before mating gypsy moth female take off is more probable from the surfaces, slightly leaned backwards (100-130° to horizon), and individuals on surfaces with slope less than vertical have higher tendency to walk; while position completely upside down seems to stop walking but not flying. After mating, before egg laying gypsy moth females tried to escape 70° slope, the sur-

face closest to horizon in our experiments, both walking away (41.0% cases) or flying (53.8%), while on surfaces with all other inclinations egg deposition starts at mating place in 42.1-56.5% cases.

The revealed female capability to fly should also change our considerations of European gypsy moth spread and migration. Unusual mass flight of this moth in Moscow was recorded earlier (Gornostajev 1962), and males with air currents can possibly cover up to 1100 kilometers in few days (Mikkola 1971). Females should be less efficient in flight distance, but a lot of females cast ashore from the sea in Lithuania in 1995 clearly demonstrate their migratory habit, and a new outbreak area in Silute county (fig. 1) suppose few dozen kilometers to be surmounted distance. Rise of outbreak at the significant distance in 1996 should be attributed to migrating females. Uncertainty remains only on flying female hazard - to what extent this new outbreak was initiated by migrating gypsy moth females, or did entering individuals shift local population balance over outbreak limit, as gypsy moth was found as species in most of Lithuania (Kazlauskas, 1984). Therefore, risk due to flying gypsy moth females need further clarification.

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СПОСОБНОСТЬ ПОЛЁТА САМОК НЕПАРНОГО ШЕЛКОПРЯДА (*LYMANTRIA DISPAR* L.) В ЛИТВЕ

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Резюме

Полет в поведении непарного шелкопряда наблюдался у 17.3% нормально спаривавшихся и у 50.0% самок с трехдневной задержкой копулирования; хождение - у 55.8% и 19.1%, пассивность - в 26.9% и 30.9% самок, соответственно. После спаривания летало 30.0% и 37.3% самок (нормальное и задержанное спаривание), 40.0% и 25.5% ходило, 30.0% и 37.3% не сдвинулись и отложили кладки непосредственно на месте спаривания. Полет самок зафиксирован у 37.3-52.9% самок, находящихся на поверхностях с углами наклона 70°, 100°, 130° и 180° (вниз головой); при 180° варианте ходило достоверно меньше самок (20.6%) по сравнению со всеми другими углами наклона (54.9-37.1%); значительно меньше самок (26.5%) оставалось неподвижными вверх ногами по сравнению с другими положениями (2.3-7.8%). После спаривания с 70° поверхности улетало больше самок (53.8%) чем с других поверхностей (21.1-34.3%); откладка яиц на месте спаривания наблюдалось в 42.1-48.6% случаев, за исключением варианта с 70° углом наклона (5.1%).

Ключевые слова: непарный шелкопряд, *Lymantria dispar*, самка, полет..