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Factors affecting *Lymantria dispar* mortality in a willow wood in northern Italy

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Abstract

Mortality factors affecting a *Lymantria dispar* (L.) (Lepidoptera Lymantriidae) population in a willow wood next to the Po River (northern Italy) were studied from 1997 to 2007. In that period population density of *L. dispar* was low, ranging from 5.5 egg masses /100 trees to 18.8 egg masses/100 trees. Willow woods are not the most suitable habitat for gypsy moth populations, which rarely increase to an epidemic level on this host. Mortality is affected by the action of several natural enemies: *Anastatus japonicus* Ashmead (egg parasitoid), *Dermestes lardarius* L. (egg predator) and *Compsilura concinnata* (Meigen) (larval parasitoid). An important control factor is represented by floods, which lay a sediment of mud at the base of the trees, so burying egg masses laid near to the soil. In addition, the flooding water, which is rich of suspended solids, leaves a layer of sludge on the surface of the bark, which can suffocate egg masses. The percentage of egg masses which did not hatch at all (100% mortality) because of sludge left on the bark was 17.2% in 1999 and 64.7% in 2000. Outbreaks of the gypsy moth can rarely occur when the effects of both natural enemies and floods are simultaneously reduced.

Key words: *Lymantria dispar*, willow woods, natural enemies, abiotic factors, floods.

Introduction

The gypsy moth, *Lymantria dispar* (L.) (Lepidoptera Lymantriidae) is one of the most important forest pests. It is a polyphagous defoliator; it can feed on over 400 host plants (including *Quercus*, *Malus*, *Alnus*, *Tilia*, *Populus*, *Salix*). The most suitable habitats are woods dominated by *Quercus* species (Simionescu and Stefanescu, 1978), such as cork oak woods in the Mediterranean basin (Luciano and Prota, 1985; Fraval, 1986; Luciano, 1995) where population density fluctuates cyclically (gradation). Periods of latency are followed by a rapid increase up to a peak density (Bariselli *et al*., 1994; Luciano and Prota, 1985; 1989). After the peak density has been reached, the population level plunges to a new latency phase (Luciano, 1995).

In less suitable habitats, such as willow woods (Barbosa and Krischik, 1987; Cook *et al*., 2003), severe defoliations are rare events, but they might occur. At the end of the 80s, for example, two willow woods in northern Italy (Arena Po, Spessa Po - province of Pavia) were devastated by *L. dispar*. This paper details the factors which can affect the gypsy moth population dynamics in willow woods next to the river Po, in northern Italy.

Materials and methods

The study area (19.1 hectares) is located at Pancarana (province of Pavia, 45°4′52″N - 9°3′16″E) next to the Po River. It includes an almost pure willow wood (*Salix alba*) with only a few poplars (*Populus alba*, *P. hybrida euroamericana*). Dead trees are generally cut and removed in winter.

The area is crossed by a pathway used to get to the river; at both sides of the pathway two random points were chosen in order to find reference landmarks for egg masses counting and tree density estimates, for a total of four random points inside four counting plots.

According to a method frequently used for this purpose, starting from each of the four random points, 40 trees set in a cross-like shape were chosen. Each cross of trees had as a crossing point one of the random points, while each arm of the cross was composed of 10 trees in a row pointing at the four cardinal points (Luciano and Prota, 1986) so that all together 160 trees were used as a sample to carry out egg masses counting. Egg masses were monitored from 1997 to 2007; trees were measured at 1.3 m above the soil line to determine circumference and height of individual egg masses above the soil. In 1997 and 2007 the trees density was estimated by measuring the number of stems inside four circular plots (12 meter radius) having as a centre the four reference landmark points used for egg masses counting. Trees density decreased from 204.6/ha in 1997 to 193.6/ha in 2007.

Egg masses exposition and predation by arthropods and birds was monthly monitored from September 1999 to April 2000 by checking a sample of 100 marked egg masses randomly chosen within the central part of the wood. Every sign which could be made by predators, such as removal, stripping or lifting of egg masses parts (Villemant, 1998; Villemant and Fraval, 1992) was recorded.

The amount of predation was estimated by using the visual scale of Higashiura (1980; 1989) which proposes six levels of predation, according to the percentage of egg mass removed, that is 10, 30, 50, 70, 90 and 100%.

The activity of egg parasitoids was studied by checking marked samples of egg masses in the biological seasons 1998-1999 and 1999-2000 (September - April).

Parasitoids were also studied by holding samples of larvae fed with fresh willow leaves until the final moult into pupa.

Mortality due to floods was assessed by observing

samples of egg masses submerged by water in order to calculate the percentage of egg masses with no hatching (100% mortality) because of sludge left on the bark of trees.

The study area in Pancarana was preferred to other willow woods next to Po river: Arena Po (10.7 ha), Spessa Po (32.4 ha) and Bastida Pancarana (15.3 ha). In 1997 the egg masses density in those areas was too low to conduct research on *L. dispar* and its possible natural enemies. Anyway, some egg counts were performed in 1998 and 1999 also in Spessa Po, Arena Po and Bastida Pancarana, according to the method previously described. In Bastida Pancarana samples of egg masses were also marked in order to assess the activity of egg parasitoids.

Results

Lymantria dispar life cycle

In the studied willow woods, gypsy moth eggs hatch from April to May; larvae moult into pupae in July and adult females stop laying egg masses during the first half of August.

Egg masses density and height

Figure 1 displays the change in egg masses density from year to year: density is expressed as the number of egg masses/100 trees and is taken directly from counts of egg masses in the four plots. Except for the year 1998, egg masses density was low, ranging from 5.5 egg masses/100 trees to 18.8 egg masses/100 trees.

The same tendency was recorded in the woods in Arena Po, Spessa Po and Bastida Pancarana. Low densities were found in 1998: 2.5 egg masses/100 trees in Arena Po and 3.2 egg masses/100 trees in Spessa Po. In the study area in Bastida density was of 10.8 egg masses/100 trees in 1998 and 6 egg masses/100 trees in 1999.

Table 1 summarizes data on tree circumference (1997-1999) as measured in Pancarana willow wood. The statistical z test ($z = 0.03$) showed no significant difference between the average circumference of trees (total sample) without or with egg masses, which means there was no preference related to tree dimensions when adult females laid eggs.

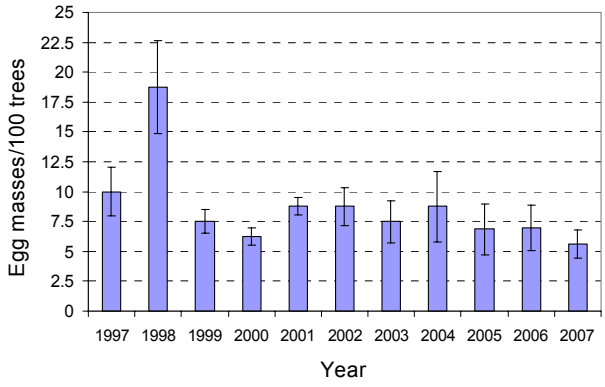

Figure 1. Egg masses density (masses/100 trees) from 1997 to 2007 in Pancarana willow wood; SE is shown.

Table 1. Average circumference (± Standard Deviation) of checked trees and trees with egg masses (years 1997-99) in the study area in Pancarana.

Sample of trees (n)	480
Circumference ± S.D. (cm)	71.84 ± 18.62
Egg masses (n)	58
Trees with egg masses (n)	38
Trees with egg masses (%)	7.9
Circumference of trees with eggs (cm)	72.98 ± 18.80

Table 2. Egg masses height on trunks (years 1997-2007) in Pancarana willow wood (Average ± S.D).

Egg masses (n)	153
Average height (cm)	106.82 ± 43.93

The height of egg masses on the bark is related to population density; in cork oak woods in Sardinia gipsy moths tend to lay eggs on lower parts of the tree during the latency phase (within 2 meters from soil), while the height tends to increase as density increases (Luciano and Prota, 1979). In table 2 data on egg masses height are shown.

In the study area in Pancarana 81% of egg masses were laid at < 1.5 meters above the soil line. Figure 2 displays the frequency distribution of egg masses height, which is a very important factor because mortality due to flooding affects egg masses closer to the soil more than those higher up on the tree.

Egg masses exposition

Figure 3 shows frequency distribution of egg masses in relation to cardinal direction. Cardinal direction was recorded for each of the 100 egg masses marked and monitored for evaluating also predation by birds and arthropods. Based on a χ^2 test (22.72) moths tend to preferentially lay their eggs on the South, South East, South West ($P < 0.01$) side of trees. This preference is probably due to the need for solar heat required for egg hatch.

Natural enemies: egg masses predation

Figure 4 displays the time trend of egg masses predation and parasitization. The most important gypsy moth

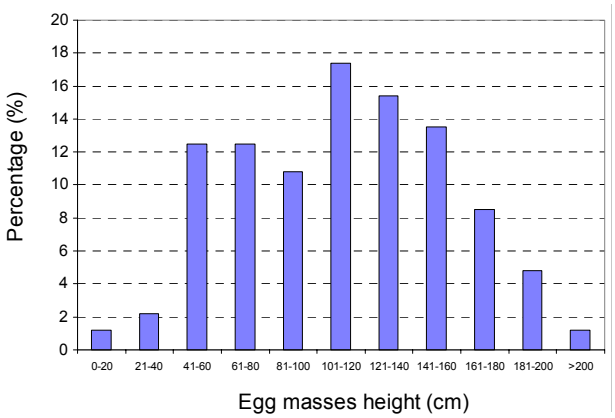

Figure 2. Frequency distribution of egg masses height in Pancarana willow wood (1997-2007; n = 153).

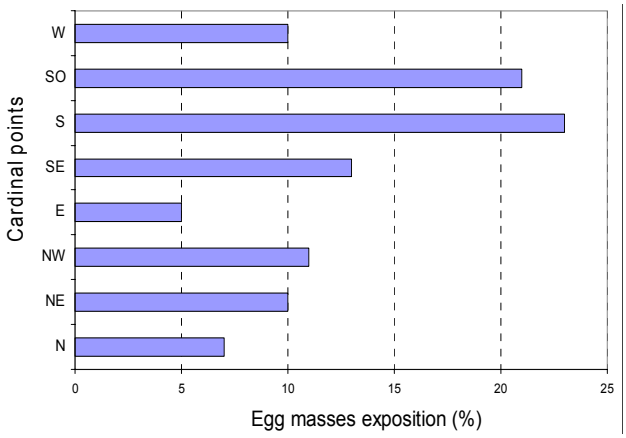

Figure 3. Egg masses exposition (%) in Pancarana willow wood (n = 100).

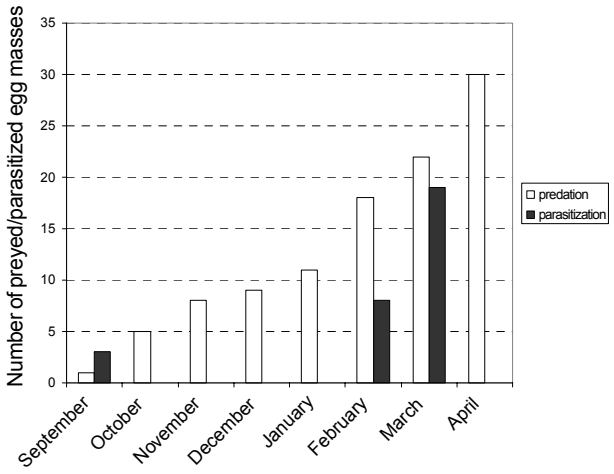

Figure 4. Cumulative number of egg masses showing signs of predation and parasitization in Pancarana willow wood (September 1999- April 2000, n = 100).

egg predators in the Mediterranean region belong to Coleoptera Dermestidae: *Anthrenus vladimiri* Menier et Villemant, *Dermestes lardarius* L. and *Trogoderma versicolor* (Creutzer) (Menier and Villemant, 1993; Villemant and Ramzi, 1995; Villemant and Andrei-Ruiz, 1999).

In Pancarana area, *D. lardarius* and *Allothrombium* sp. (Acarina) were both observed on eggs masses, but while *D. lardarius* is capable of actively penetrating the gypsy moth egg masses, *Allothrombium* sp. can only feed on eggs after they have been uncovered by other predators. In northern Italy *Allothrombium* sp. was recognized as a predator of *Hyphantria cunea* (Drury) (Lepidoptera Arctiidae) eggs (Camerini and Groppali, 1999).

It is reasonable to assume that birds also contributed to egg mass predation (Campbell, 1975; Higashiura, 1980; 1989). In some cases egg mass damage was consistent with the use of a sharp object, like a beak, to remove eggs, which could not be caused by arthropods. In willow woods next to the Po River insectivorous birds such as the great tit (*Parus major* L.) are common all year long; in winter they face a lack of prey and therefore they tend to shift their trophic niche to usually neglected resources, such as insects eggs.

Moreover some marks on the bark (bark stripping, extraction holes) next to some partially removed egg masses suggest predation by the great spotted woodpecker [*Dendrocopos major* (L.)], which in winter actively visits willow woods and poplar plantations searching for *Cossus cossus* (L.) (Lepidoptera Cossidae) larvae and other xilophagous insects (Camerini, 1998).

Thirty egg masses showed marks of predation (figure 4) and in those egg masses the amount of eggs removed was on average 21%.

Natural enemies: egg parasitoids

Samples of marked egg masses were monitored to evaluate egg parasitoid activity (figure 4). The presence of thin holes made by parasitoids emerging from the egg mass was used as evidence that oophagous insects were active. Holes appeared in August-September and in February-March. A sample of the wasps coming from *Lymantria* eggs or captured on egg mass surfaces were determined to be *Anastatus japonicus* Ashmead (= *disparis* Ruschka) (Hymenoptera Eupelmidae).

In central Italy *A. japonicus* (Roversi, 1990) develops two complete generation/year and starts a third generation over the winter: the observation of *A. japonicus* on egg masses in August agrees with Roversi data, but the adult emergence after the winter was different, since in willow woods it is earlier and apparently not synchronized with host life cycle in spring.

Table 3 summarizes data on egg masses showing signs of parasitization.

Natural enemies: larvae parasitoids

During summer 1999 a sample of gypsy moth larvae was collected from tree trunks in order to assess the effect of parasitoids on mortality. The total number of reared larvae was 323: 126 second-third instar larvae and 197 mature larvae): table 4 shows the results of rearing. A mortality of 47% was recorded, due to pathogens and stress conditions associated with rearing: 99 moths and 72 parasitoids were obtained.

Based on table 4, the only effective larvae parasitoid appeared to be *Compsilura concinnata* (Meigen), which

Table 3. Egg masses with signs of parasitization.

Study area	Season	Egg masses sample (n)	Egg masses with signs of parasitization (n)	% of egg masses with signs of parasitization
Pancarana	1998-99	36	10	27.8
Bastida Pancarana	1998-99	40	13	32.5
Pancarana	1999-00	100	19	19
Bastida Pancarana	1999-00	41	9	21.9

Table 4. Parasitoids obtained by the sample of 323 *L. dispar* larvae collected in Pancarana willow wood.

Parasitoid	Adults obtained by rearing
Compsilura concinnata (Meigen) (Diptera Tachinidae)	65
Aphantorhaphopsis samarensis (Villeneuve) (= *C. samarensis*) (Diptera Tachinidae)	1
Blepharipa pratensis (Meigen) (Diptera Tachinidae)	4
Meteorus pulchricornis (Wesmael) (Hymenoptera Braconidae)	1
Cotesia melanoscela (Ratzeburg) (Hymenoptera Braconidae)	1

Table 5. Effects of floods on submerged egg masses survival. "No hatching" = 100% mortality.

Study area	Season	Sample of submerged egg masses (n)	Egg masses with no hatching (n)	Egg masses with no hatching (%)
Pancarana	1998-99	87	15	17.2
Pancarana	1999-00	34	22	64.7

in northern Italy is also known as a natural enemy of the defoliator *H. cunea* (Camerini and Groppali, 1999). In Sardinia's cork oak woods the action of *C. concinnata* against *L. dispar* is negligible (Luciano and Prota, 1981).

Other parasitoids, such as *Brachymeria tibialis* (Walker) (= *intermedia* Nees) (Hymenoptera Chalcididae) and *Exorista larvarum* (L.) (Diptera Tachinidae) are listed as enemies of the gypsy moth in Sardinia and are also known as parasitoids of *H. cunea* in the Po river basin (Camerini and Groppali, 1999) but they have not been observed as enemies of the gypsy moth in the study area.

Abiotic factors: floods

In willow woods next to rivers egg masses laid on trunks can be submerged by water during floods (Netoiu and Tomescu, 2007). In the river Po's basin, floods generally occur in spring and autumn. The layer of sludge left on egg mass surfaces can affect the success of eggs hatching. As a result of a flood between 5th and 6th May 1999, 87% of the egg masses marked for predation study were submerged and 17% of them did not hatch at all (table 5).

Similar effects can derive from autumnal floods: in October 1999 a flood left at 30 to 60 cm thick sediment of mud at the base of trees so burying those egg masses laid nearer to the soil. In addition, water left a thick sludge layer on trunks up to a height of 1.5 meters, so suffocating the 64.7% of submerged egg masses, that did not hatch at all (table 5). In the study area, 81% of egg masses were laid at less than 1.5 m from soil; these data state that floods can play an important role as a mortality factor.

Discussion

In the most suitable habitats, such as oak woods, *L. dispar* population density changes are periodical and mortality is indirectly influenced by phytoclimatic factors, which affect both food quality and quantity. Biotic factors are important too (Campbell, 1975), since they act in a density dependent way: natural enemies reduce the gypsy moth population after an outbreak (Luciano and Prota, 1981; 1989). A decline of population density is also caused by intraspecific competition: when the whole biomass of leaves has been consumed, the mortality increases rapidly because of dispersion, famine, weakening and crowding, which favour the action of predators and the spread of pathogens (Luciano and Prota, 1986).

Both observations carried out from 1997 to 2007 in the study areas and forest health information collected by regional offices confirm that *L. dispar* population density in willow woods tends to be low, due to natural enemies and floods; outbreaks are not frequent.

Egg masses survival is affected by the thickness of the sludge layer which is left on the trunks and by the quantity of mud laid as sediment at the base of trees as a consequence of floods. Those factors depend on the duration of flood and on the level of flooding water. Egg masses laid next to the ground can be buried by the sedimentation of mud, while egg masses laid on higher parts can be suffocated by the layer of dried sludge covering the bark.

At low densities, egg masses of the gypsy moth are laid by females in the lower part of trunks, so that submersion due to floods has a strong effect on mortality.

Outbreaks of the moth are rare and they probably occur when the effects of both natural enemies and floods are simultaneously reduced.

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