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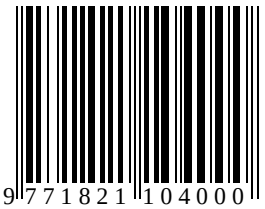

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Original scientific paper

GYPSY MOTH, *Lymantria dispar* (L.), AND ITS NATURAL ENEMIES IN THE FORESTS OF CENTRAL SERBIA

Mara TABAKOVIĆ-TOŠIĆ[1]

Abstract: *In central Serbia, a total of 88 species which are natural enemies of the gypsy moth, i.e. 23 predators, 49 parasitoid insects and 10 saprophagous insects, and 6 pathogens*, *has been reported. The most abundant of them are the insects which attack the gypsy moth in the larval instar (41 species). Regarding the number of the species, the representatives of the Hymenoptera (14 species from Ichneumonidae family and 11 species from Braconidae family) and Diptera orders (12 species from Tachinidae family and 8 species from Sarcophagidae family) are most frequent. Regarding the predators of the gypsy moth, Carabidae family, from Coleoptera order, is most frequent. In addition, at some sites Lymantria dispar nucleopolyhedrosis virus and Entomophaga maimaiga had the dominant role in the reduction of the gypsy moth density.*

Key words: the gypsy moth, predators, parasitoids, pathogens

GUBAR, *Lymantria dispar* (L.), I NJEGOVI PRIRODNI NEPRIJATELJI U ŠUMAMA CENTRALNE SRBIJE

Izvod: *U centralnoj Srbiji do danas je utvrđeno ukupno 88 vrste prirodnih neprijatelja gubara, i to 23 predatora, 49 parazitoida, 10 vrsta koje se ponašaju kao saprofagi i parazitoidi, te 6 patogena. U navedenom broju najzastupljeniji su insekti koji parazitiraju larveni stadijum gubara (41 vrsta). Po broju zastupljenih vrsta, najviše je pripadnika redova Hymenoptera (12 vrsta iz familije Ichneumonidae i 11iz familije Braconidae) i Diptera (12 vrsta iz familije Tachinidae i 8 iz Familije Sarcophagidae). Od predatora gubara, najzastupljenija ja familija Carabidae iz reda Coleoptera. Takođe, u pojedinim područjima Lymantria dispar nucleopolyhedrosis virus i entomopatogena gljiva*

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Entomophaga maimaiga imali su dominantnu ulogu u smanjenju brojnosti gubara u stadijumu larve.

Ključne riječi: gubar, predatori, parazitoidi, patogeni

1. INTRODUCTION

The gypsy moth (*Lymantria dispar* L.), insect in the order *Lepidoptera*, is one of the most dangerous pests of broadleaf forests and orchards. It is characterised by a high reproductive capacity, considerable ecological plasticity and polyphagia. It occurs periodically in high numbers (outbreak). Although it is found on four continents (North Africa, Asia, Europe, North America), the greatest damage is caused to the forests of the Balkan Peninsula, which have all favourable environmental conditions for the gypsy moth development, and it often occurs in outbreaks.

Biological control, as the part of the forest integrated protection, is defined as the use of natural enemies (parasitoids, predators, and pathogens) to regulate or control pests. Various strategies have been used for the enhancement of biological control agents. Classical biological control is simply a special case of a general pattern in which populations are regulated by density-dependent processes, a major class of which involves predator-prey or parasitoid-host interactions.

Recent emphasis on the development of an integrated control program for the gypsy moth has necessitated an understanding of its mortality-causing biological agents. Throughout the holarctic region there is a wide range of natural enemies of this insect. The diseases caused by viruses, bacteria or fungi contribute to the decline of gypsy moth populations. For example, baculovirus – *Lymantria dispar* nucleopolyhedrosis virus (*Ld*NPV) is specific to the gypsy moth, the most devastating natural disease, and it causes a dramatic collapse of outbreak populations by killing both the larvae and pupae. Infection by *Ld*NPV is the most common source of mortality in high density populations and *Ld*NPV epizootics, since it usually causes the collapse of host populations (Evans, 1986; McCoy et al., 1988).

Second example is the entomopathogenic fungus *Entomophaga maimaiga* Humber, Shimazu & Soper (Entomophtorales: Entomophtoraceae) which was isolated and described as the natural enemy of the gypsy moth in Japan, where it causes the periodical epizootias. It is also spread in some parts of China and the Russian Far East (Hajek et al., 2005). In spite of the fact that it was introduced in North America in 1910-1911 (Speare and Colley, 1912), its presence in the natural populations of gypsy moth was determined only in 1989 (Hajek et al., 1996), when the pathogen caused pandemic in several countries (Andreadis and Weseloh, 1990; Hajek et al., 1990; Reardon and Hajek, 1998; Smitley et al., 1996). Today *Entomophaga maimaiga* is a very significant pathogen of gypsy moth in North America and Canada (Balser and Baumgard, 2001; Hajek, 1997; Hajek et al., 2005; Hoover, 2000; Howse and Scarr, 2002).

Bulgaria has been the third country in the world and the first one in Europe in which *Entomophaga maimaiga* was introduced successfully (Pilarska et al.,

2000). The first epizootics of it occurred in 2005 (Georgiev et al., 2007, 2010; Pilarska et al., 2006). This species is also present in oak forests in some Serbian regions (Tabaković-Tošić et al., 2012a, 2013- in press).
This paper presents the author's published and unpublished results of survey of the natural enemies (predators, parasitoids and pathogens) of the gypsy moth in Central Serbian forests, supplemented by available published results of other authors.

2. MATERIALS AND METHODS

Central Serbia, the area where the occurrence, population size and intensity of the adverse effects of the natural hosts of the gypsy moth were studied, is located in the centre and southeastern part of Republic of Serbia. It covers an area of about 55,000 square kilometers. It is located between 42 and 45 degrees northern latitude and between 19 and 23 degrees eastern longitude.

In Central Serbia, forests cover an area of 2.1 million hectares (37,6% of the total area), of which 51% is the state property and 49% is the private property, timber volume amounts to 333 million m^3 (59.2% in state forests and 40.8% in private forests), and volume increment is 3.9 m^3/ ha^{-1} (56.6% in state and 43.4% in private forests); broadleaves account for 86.9% of the total timber volume (beech 43.9%, oaks 26.3%, other broadleaves 29.8%) (Banković et al., 2009).

Every year over the last twenty years period, in all broadleaf forests, a survey of main predators, parasitoids and pathogens was conducted from April to late November during studies of the population dynamics and outbreaks of the gypsy moth (Tabaković-Tošić et al., 2002; Tabaković-Tošić, 2004, 2006, 2011).

The studies of the presence and density of the main predator species of the gypsy moth were conducted by using the methods, typical for some families to which the insects belong.

The detailed quantitative and qualitative studies of the parasitisation rate of the sampled egg masses were conducted in the laboratory of the Institute of Forestry, and, depending on the observed parameter, either ocular method or method of the survey by using binocular magnifier was applied. From each egg mass, 100 randomly sampled, previously cleaned eggs, were placed in the specially prepared test tubes. The emergence of the imago parasitoids was reported every day until the end of the process.

The field-collected larvae and pupae were grown under the laboratory conditions in the climate chamber. During the all laboratory experiments, temperature and light conditions were constant (temperature 21°C, light regime - 8 hours night, 16 hours a day).

The studies of the presence of entomopathogenic viruses, bacteria and fungi in the dead gypsy moth larvae were conducted in the field and laboratory conditions. In the field conditions the characteristic symptoms of some diseases were identified by using ocular method, while in the laboratory conditions, they were identified by dissection of the dead larvae and the microscope survey (Tabaković-Tošić et al., 2012).

3. RESULTS AND DISCUSSION

Natural enemy populations have the unique ability to interact with their prey or host populations and to regulate them at lower levels than would occur otherwise. Some are effective at extremely low prey levels, other only at higher levels.

In biological control parlance, natural enemies are referred to as parasitoids, predators or pathogens. Parasitoids may have one (univolutine), two or more generations to one of the host (multivolutine), and they tend to attack only one host stage, although there is also some overlapping in certain cases – adult insects do not serve as hosts very often (Debach, 1974). Predatory insects differ from parasitic ones since the larvae or nymphs, as the case may be, require several or many prey individuals to attain maturity.

Pathogenic microorganisms attack insects and have life cycles more or less characteristic of similar micro-organisms developing in other groups of animals. Insects are probably subject to as wide a variety of diseases. A number of pathogenic microorganisms – viruses, bacteria, fungi, and microsporidia (for example: *Lymantria dispar* nucleopolyhedrosis virus, *Bacillus thuringiensis* Berliner, *Entomophaga maimaiga* Humber, Shimazu & Soper, *Nosema lymantriae* (Weiser), *Nosema serbica* Weiser*)* – infect the gypsy moth (Pilarska and Vávra, 1991; Sidor, 1979; Stiles et al., 1983; Tabaković-Tošić, 2008; Tabaković-Tošić et al., 2011a,b; Weiser, 1998). The epizootics of them are often spectacular, and mortality is most prevalent during gypsy moth outbreaks.

Based on the literature data, a total of 81 species which are natural enemies of the gypsy moth, i.e. 17 predators, 49 parasitoids, 10 saprophagous insects, and 5 pathogens, have been reported in Central Serbia (Table 1). The parasitoids which attack the larval instar of the gypsy moth are most frequent (31 species), followed by the predators of the gypsy moth eggs (12 species), the parasitoids of the pupae of the host (13 species), saprophages and parasitoids of the same instar (10 species), predators of the larvae 5 species), parasitoids of the gypsy moth eggs (5 species), pathogens of the larvae (5 species) (Table 1).

During the observed period, in the gypsy moth populations, the activity of 59 natural enemies of this insect - twenty-one predators, twenty-nine parasitoids, seven parasitoids or saprophagy and two pathogens -was reported. The gypsy moth eggs were attacked by thirteen species of the predators, larvae by six species, and larvae and pupae by two species.

There were three parasitoids species of the gypsy moth eggs, nineteen parasitoids species of the gypsy moth larvae, and seven parasitoids species of the gypsy moth pupae. Parasitoids or saprophages of gypsy moth pupae were represented by seven species. Two pathogenic species (*Ld*NPV and *Entomophaga maimaiga*) has been identified. (Table 1).

Table 1. *Natural enemies of the gypsy moth in the forests of Central Serbia*

Gypsy moth		**Significance**	
Natural enemies	**Instar**	**Literature sources**	**Personal research**
PREDATORS			
Trombidium holosericeum (Linnaeus, 1758)	egg	+++	+++

Gypsy moth		**Significance**	
Natural enemies	**Instar**	**Literature sources**	**Personal research**
[Acari: Trombiculidae]		[9, 11]*	[6]**
Forficula auricularia Linnaeus, 1758 [Dermaptera: Forficulidae]	egg	+++ [9, 11]	+++ [6]
Dermestes lardarius Linnaeus, 1758 [Coleoptera: Dermestidae]	egg	-	++ [3]
Dermestes erichsoni Ganglbauer, 1904 [Coleoptera: Dermestidae]	egg	+++ [11, 12]	++ [1, 2, 3, 6]
Megatoma pici Kalik, 1952 [Coleoptera: Dermestidae]	egg	+++ [11, 12]	++ [1, 2, 3, 6]
Megatoma pubescens (Zetterstedt, 1828) [Coleoptera: Dermestidae]	egg	++ [11, 12]	+ [6]
Megatoma undata (Linnaeus, 1758) [Coleoptera: Dermestidae]	egg	++ [9, 11]	+ [6]
Ctesias serra (Fabricius, 1792) [Coleoptera: Dermestidae]	egg	++ [11, 12]	-
Globicornis nigripes (Fabricius, 1792) [Coleoptera: Dermestidae]	egg	++ [11, 12]	+ [6]
Julistus floralis (Olivier, 1790) [Coleoptera: Cantharidae]	egg	+++ [9, 11, 12]	+ [1, 2, 3, 6]
Malachus bipustulatus (Linnaeus, 1758) [Coleoptera: Cantharidae]	egg	+++ [11, 12]	+ [6]
Podisus maculiventris (Say, 1832) [Heteroptera: Pentatomidae]	egg	+ [11, 12]	+
Formica rufa Linnaeus, 1758 [Hymenoptera: Formicidae]	egg	++ [4, 9]	+ [6]
Carabus latus Dejean, 1826 [Coleoptera: Carabidae]	egg	-	+ [3, 6]
Silpha quadripunctata Schreber, 1759 [Coleoptera: Silphidae]	larvae	++ [11, 12]	+++ [6]
Xylodrepa quadripunctata (Linnaeus, 1758) [Coleoptera: Silphidae]	larvae	+ [9]	-
Carabus coriaceus (Linnaeus, 1758) [Coleoptera: Carabidae]	larvae	-	+ [1, 2, 3, 6]
Carabus cancellatus (Linnaeus, 1758) [Coleoptera: Carabidae]	larvae	++ [9, 12]	+ [1, 2, 3, 6]
Carabus cavernosus Frivaldsky, 1837 [Coleoptera: Carabidae]	larvae	-	+ [1, 2, 3, 6]
Carabus intricatus (Linnaeus, 1758) [Coleoptera: Carabidae]	larvae	-	++ [1, 2, 3, 6]
Carabus scabriusculus bulgarus Lapouge, 1908 [Coleoptera: Carabidae]	larvae	-	+ [1, 2, 3, 6]
Calosoma sycophanta (Linnaeus, 1758) [Coleoptera: Carabidae]	larvae/pupae	+++ [5, 9, 12, 19]	+++ [1, 2, 3, 6]
Calosoma inquisitor (Linnaeus, 1758) [Coleoptera: Carabidae]	larvae/pupae	++ [9, 12]	++ [1, 2, 6]
PARASITOIDS			
Anastatus japonicus Ashmead, 1904 [Hymenoptera: Eupelmidae]	egg	+++ [9, 12, 20, 21]	++ [1, 2, 3, 4, 6]
Ooencyrtus kuwanae (Howard, 1910) [Hymenoptera: Encyrtidae]	egg	+++ [9, 12]	+++ [1, 2, 3, 4, 6]
Ooencyrtus tardus (Ratzeburg, 1844) [Hymenoptera: Encyrtidae]	egg	+ [9]	-
Ooencyrtus masii (Mercet, 1921) [Hymenoptera: Encyrtidae]	egg	+ [9]	-
Eremioscelio lymantriae Masnil, 1958 [Hymenoptera: Scelionidae]	egg	++ [9, 12]	+ [6]
Casinaria tenuiventris (Gravenhorst, 1829) [Hymenoptera: Ichneumonidae]	larvae	+ [9, 12, 20]	+ [6]

Gypsy moth		Significance	
Natural enemies	**Instar**	**Literature sources**	**Personal research**
Phobocampe disparis (Viereck, 1911) [Hymenoptera: Ichneumonidae]	larvae	++ [8, 9, 10, 12, 13, 20]	+ [6]
Phobocampe pulchella (Thomson, 1887) [Hymenoptera: Ichneumonidae]	larvae	+++ [9, 12]	++ [6]
Apanteles glomeratus (Linnaeus, 1758) [Hymenoptera: Braconidae]	larvae	+ [9]	+ [3, 6]
Apanteles lacteicolor Viereck, 1911 [Hymenoptera: Braconidae]	larvae	++ [9, 10, 12, 23]	+ [3, 6]
Cotesia melanoscela (Ratzeburg, 1844) [Hymenoptera: Braconidae]	larvae	+++ [1, 3, 6, 7, 8, 9, 10, 12, 13, 20, 21, 23]	++ [1, 2, 3, 6]
Cotesia ocneriae (Ivanov, 1898) [Hymenoptera: Braconidae]	larvae	+ [7, 9, 10, 12, 23]	+ [6]
Cotesia scabricula (Reinhard, 1880) [Hymenoptera: Braconidae]	larvae	+ [9, 12]	+ [6]
Cotesia spuria (Wesmael, 1837) [Hymenoptera: Braconidae]	larvae	+ [9, 12]	-
Protapanteles liparidis (Bouček, 1834) [Hymenoptera: Braconidae]	larvae	++ [1, 8, 9, 12, 20, 23]	++ [1, 2, 3, 6]
Protapanteles porthetrie Muesebeck, 1954 [Hymenoptera: Braconidae]	larvae	+++ [6, 9, 10, 12, 17, 20, 21, 23]	++ [6]
Protapanteles fulvipes (Haliday,1834) [Hymenoptera: Braconidae]	larvae	+ [9, 12]	+ [6]
Meteorus versicolor (Wesmael, 1835) [Hymenoptera: Braconidae]	larvae	+ [8, 9, 10, 12]	+ [6]
Meteorus gyrator (Thunberg, 1822) [Hymenoptera: Braconidae]	larvae	+ [9]	-
Eulophus slovacus Bouček, 1959 [Hymenoptera: Eulophidae]	larvae	+ [9]	-
Cirrospilus pictus (Nees, 1834) [Hymenoptera: Eulophidae]	larvae	+ [9]	-
Elachertus charondas (Walker, 1839) [Hymenoptera: Eulophidae]	larvae	+ [9]	-
Euplectrus liparidis Ferrière, 1941 [Hymenoptera: Eulophidae]	larvae	+ [9]	+ [6]
Sympiesis sericeicornis (Nees, 1834) [Hymenoptera: Eulophidae]	larvae	+ [9]	-
Exorista larvarum (Linnaeus, 1758) [Diptera: Tachinidae]	larvae	+++ [4, 12, 14, 22]	+ [3, 6]
Parasetigena silvestris (Robineau-Desvoidy, 1863) [Diptera: Tachinidae]	larvae	+++ [4, 12, 13, 14, 15, 17]	++ [6]
Phorocera agilis (Robineau-Desvoidy, 1830) [Diptera: Tachinidae]	larvae	+ [9]	-
Blondelia nigripes (Fallen, 1810) [Diptera: Tachinidae]	larvae	+ [1, 9, 12, 16]	-
Compsilura concinnata (Meigen, 1824) [Diptera: Tachinidae]	larvae	+++ [1, 9, 12, 14, 15, 16, 17, 22]	+ [3, 6]
Drino inconspicua (Meigen, 1830) [Diptera: Tachinidae]	larvae	+ [9, 12, 14, 16, 22]	-
Carcelia lucorum (Meigen, 1824) [Diptera: Tachinidae]	larvae	+ [9]	-
Carcelia gnava (Meigen, 1824) Syn. *Senometopia separata* (Rondani, 1859) [Diptera: Tachinidae]	larvae	+ [9, 12, 16, 22, 24]	++
Senometopia susurrans (Rondani, 1859) [Diptera: Tachinidae]	larvae	+ [9, 12, 14]	-
Zenillia libatrix (Panzer, 1798) [Diptera: Tachinidae]	larvae	+ [9, 16]	-

Gypsy moth		Significance	
Natural enemies	**Instar**	**Literature sources**	**Personal research**
Blepharipa pratensis (Meigen, 1824) [Diptera: Tachinidae]	larvae	+++ [1, 4, 9, 12, 14, 16, 17, 22]	++ [1, 2, 3, 6]
Blepharipa schineri (Mesnil, 1939) [Diptera: Tachinidae]	larvae	++ [9, 12, 14, 16, 22]	+ [6]
Gregopimpla inquisitor (Scopoli, 1763) [Hymenoptera: Ichneumonidae]	pupae	+ [12, 20]	-
Acropimpla didyma (Gravenhorst,1829) [Hymenoptera: Ichneumonidae]	pupae	+ [9]	-
Apechtis compunctor (Linnaeus, 1758) [Hymenoptera: Ichneumonidae]	pupae	+ [9, 12, 20]	-
Apechtis capulifera (Krichbaumer, 1887) [Hymenoptera: Ichneumonidae]	pupae	+ [9]	-
Apechtis rufata (Gmelin, 1790) [Hymenoptera: Ichneumonidae]	pupae	+ [9, 12, 20, 22]	-
Pimpla instigator Fabricius, 1793 [Hymenoptera: Ichneumonidae]	pupae	++ [4, 9, 12, 20, 22]	+ [6]
Pimpla inquisitor (Scopoli, 1763) [Hymenoptera: Ichneumonidae]	pupae	+ [9, 12, 20]	+ [6]
Pimpla turionellae (Linnaeus, 1758) [Hymenoptera: Ichneumonidae]	pupae	+++ [1, 9, 20, 22]	++ [6]
Theronia atalantae (Poda, 1761) [Hymenoptera: Ichneumonidae]	pupae	+++ [8, 9, 12, 20, 22]	+ [1, 2, 3, 6]
Polytribax perspicillator (Gravenhorst,1807) [Hymenoptera: Ichneumonidae]	pupae	+ [9, 12]	-
Lymantrichneumon disparis (Poda, 1761) [Hymenoptera: Ichneumonidae]	pupae	+++ [4, 12, 20, 22]	+ [1, 2, 3, 6]
Brachimeria intermedia (Nees, 1834) [Hymenoptera: Chalcididae]	pupae	+++ [12, 20, 22]	+ [1, 2, 3, 6]
Brachimeria femorata (Panzer, 1798) [Hymenoptera: Chalcididae]	pupae	++ [9, 12]	+ [6]
PARASITOIDS OR SAPROPHAGY?			
Agria affinis (Fallén, 1817) [Diptera: Sarcophagidae]	pupae	+++ [9, 12, 14]	++ [6]
Agria monachae Kramer, 1908 [Diptera: Sarcophagidae]	pupae	+ [9, 12]	-
Kramerea schuetzei (Kramer, 1909) [Diptera: Sarcophagidae]	pupae	++ [9, 12, 14, 18]	+ [6]
Parasarcophaga harpax (Pandelle, 1896) [Diptera: Sarcophagidae]	pupae	++ [9, 12, 14]	+ [6]
Parasarcophaga portshinskyi Rohdendorf, 1937 [Diptera: Sarcophagidae]	pupae	++ [9, 12, 18]	+ [6]
Parasarcophaga tuberose (Pandelle, 1896) [Diptera: Sarcophagidae]	pupae	+ [9, 12, 14, 18]	-
Parasarcophaga uliginosa (Kramer, 1908) [Diptera: Sarcophagidae]	pupae	+ [9, 12, 14, 18]	+ [6]
Robineauella pseudoscoparia (Kramer, 1911) [Diptera: Sarcophagidae]	pupae	+ [9, 12, 14, 18]	-
Muscina pabulorum (Fallen, 1817) [Diptera: Muscidae]	pupae	+ [9, 12]	+ [6]
Muscina stabulans (Fallen, 1817) [Diptera: Muscidae]	pupae	+ [9, 12]	+ [6]
PATHOGENS			
Lymantria dispar nucleopolyhedrosis virus [baculovirus]	larvae	+++ [9]	+++ [3, 5, 6]
Thelohania spp. [Microsporidia: Thelohaniidae]	larvae/pupae	? [9]	-
Vairimorpha sp.	larvae	? [2]	-

Gypsy moth		Significance	
Natural enemies	**Instar**	**Literature sources**	**Personal research**
Endoreticulatus sp.	larvae	? [2]	-
Streptococcus spp. [Lactobacillales: Streptococcaceae]	larvae	? [9]	-
Entomophaga maimaiga ***Humber, Shimazu& Soper*** [Entomophtorales: Entomophtoraceae]	larvae	-	+ [5, 6]

Legend:
+ poorly represented species ++ represented species +++ highly represented species

* [1] Đorović, [2] Glavendekić et al., 2006; [3] Maksimović, 1953; [4] Maksimović, 1973; [5] Maksimović & Sivčev, 1980; [6] Maksimović & Sivčev, 1984; [7] Maksimović & Sivčev, 1987; [8] Marović & Minić, 1987; [9] Mihajlović, 2008; [10] Minić, 1988; [11] Nonveiller, 1980; [12] Ristić et al.,1998; [13] Sisojević, 1953; [14] Sisojević, 1955; [15] Sisojević, 1959; [16] Sisojević, 1975; [17] Sisojević & Vasić, 1980; [18] Sisojević et al., 1989; [19] Tomić & Janković, 1973; [20] Vasić, 1958; [21] Vasić & Salatić, 1959; [22] Vasić & Sisojević, 1958; [23] Vasić & Minić, 1980; [24] Drea, J.J., 1981)

** Unpublished and published data: [1] Tabaković-Tošić, 2006; [2] Tabaković-Tošić and Jovanović, 2007; [3] Tabaković-Tošić, 2011; [4] Tabaković-Tošić et al., 2011a; [5] Tabaković-Tošić et al, 2012; [6] Tabakovic-Tosic et al., in press)

Regarding the density of some predator species, *Trombidium holosericeum, Forficula auricularia*, *Silpha quadripunctata*, *Calosoma sycophanta* and *Carabus sp.* were most abundant ones. *Calosoma sycophanta*, which regularly occurs during the outbreak of the gypsy moth, was found more frequently than other predator species, and it reduced the population size of the gypsy moth both in the larval and imago instars.

Table 2. *The laboratory analysis of the gypsy moth egg masses and Quantitative ratio of two species of parasitoids*

Year	Number of		Average number of fertilized eggs in egg mass				Parasitoids	
	localities	egg mass	Vital		Parasited		*Ooencyrtus kuwanae (%)*	*Anastatus japonicus (%)*
			N	%	N	%		
1993	27	270	298.9	86.4	44.6	12.9	100*	0
1994	35	350	555.9	95.0	20.5	3.5	100*	0
1995	69	690	543.8	98.7	2.8	0.5	100*	0
1996	427	4270	348.4	85.9	43.8	10.8	-	-
1997	725	7250	277.7	80.7	41.6	12.1	-	-
2002	70	700	477.6	95.5	17.3	3.5	78	22
2003	431	4310	570.7	88.3	79.9	11.2	69	31
2004	1023	10230	386.1	79.2	97.4	20.0	73	27
2005	266	2660	162.5	82.4	32.0	16.2	71	29
2009	58	580	502.5	91.6	42.3	7.7	91	9
2010	80	800	526.9	90.9	48.3	8.3	87	13
2011	120	1200	465.8	92.2	34.5	6.9	90	10

*from annual reports of Serbian report-diagnose-forecast service in the domain of forest protection

The dynamics of the emergence of the imago parasitoids were studied in the special laboratory experiment. Regarding the species of egg parasitoids, in the investigated period *Anastatus japonicus* accounted from 0 to 31%, *Ooencyrtus kuwanae* 69-100% (Table 2). The average parasitism rate should not be taken as the final one, because under these laboratory conditions it is impossible to study

all the effects of a range of parasitoids and predators to which the the egg masses are exposed in the field.

At the selected sites the cocoons of the parasitoids species from the families Braconidae and Tachinidae (Table 1) were regularly found in spring. Some species from Braconidae family (Apanteles genus) were most active in the parts of the forests with the highest insolation and whence the outbreak of the gypsy moth usually begins. Other species were considerably less frequent and were found individually (Tabakovic-Tosic et al., in press).

The activity of *Ld*NPV was reported at many sites, characterized by the extremely high population size of the gypsy moth (Tabaković-Tošić et al., 2012, Tabakovic-Tosic et al., in press).

The higher mortality rate of the older gypsy moth larval instars in 2011 and 2012 was reported in the forest complexes of Belgrade and Valjevo (Tabaković-Tošić et al., 2012, Tabakovic-Tosic et al., in press), Donji Milanovac and Negotin (new localities – unpublished results) region, in the culmination phase of the new outbreak of the gypsy moth in Serbia. By field and laboratory studies of the causes of their death, the presence of azygospores and conidiospores of the entomopathogenic fungus *Entomophaga maimaiga* was reported in the dead caterpillars. It showed to be a powerful reducer of the population size of the gypsy moth, and in both regions it caused the collapse of the outbreak in 2011 and 2012.

4. CONCLUSIONS

A total of 88 species which are natural enemies of the gypsy moth, i.e. 23 predators, 49 parasitoids insects, 10 ***saprophagous insects, and 6 pathogens***, has been reported in Central Serbia. The insects which attack the larval instar of the gypsy moth are most frequent followed by the predators of the gypsy moth eggs and the parasitoids of the pupae of the host. Regarding the number of the species, the representatives of the Hymenoptera (14 species from Ichneumonidae family and 11 species from Braconidae family) and Diptera orders (12 species from Tachinidae family and 8 species from Sarcophagidae family) are most frequent. Regarding the predators of the gypsy moth, Carabidae family, from Coleoptera order is most frequent.

In spite of such a great number of the natural hosts, outbreaks of the gypsy moth are still the regular and frequent phenomenon in the forests of central Serbia, which points to the fact that nature is not so powerful regarding this economically most harmful species of the broadleaf forests in central Serbia. For the time being, the only exception to this rule is entomopathogenic fungus *Entomophaga maimaiga*.

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frequent occurrences of the outbreak of gypsy moth in the forest ecosystems of Serbia.

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GYPSY MOTH, *Lymantria dispar* (L.), AND ITS NATURAL ENEMIES IN THE FORESTS OF CENTRAL SERBIA

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Summary

Based on the literature data, a total of 81 species which are natural enemies of the gypsy moth, i.e. 17 predators, 49 parasitoids insects, 10 saprophagous insects, and 5 pathogens, have been reported in Central Serbia. The parasitoids which attack the larval instar of the gypsy moth are most frequent, followed by the predators of the gypsy moth eggs and the parasitoids of the pupae of the host. Regarding the number of the species, the representatives of the Hymenoptera (14 species from Ichneumonidae family and 11 species from Braconidae family) and Diptera orders (13 species from Tachinidae family and 8 species from Sarcophagidae family) are most frequent. Regarding the predators of the gypsy moth, Carabidae family, from Coleoptera order, is most frequent.

During the twenty-year observed period, in the gypsy moth populations, the activity of 59 natural enemies of this insect - twenty-one predators, twenty-nine parasitoids, seven parasitoids or saprophages and two pathogens was reported. Regarding the density of some species, the most abundant predators were *Trombidium holosericeum, Forficula auricularia*, *Silpha quadripunctata*, *Calosoma sycophanta and some species from genus Carabus*, while the most abundant parasitoids were *Ooencyrtus kuwanae* (Howard) and *Anastatus japonicus* Ashmead, and pathogens *Lymantria dispar* nucleopolyhedrosis virus and *Entomophaga maimaiga* .

In the observed period, average parasitism rate of eggs in egg masses ranged from 0,5 to 20%. The greatest positive change in the activity of the parasitoids occurred during the second outbreak, from 3,5% in 2002 to 20% in 2004. Regardiong the species of egg parasites, in laboratory conditions *Oencyrtus kuwanae* was absolutely dominant (69-100%). In addition, at some sites *Lymantria dispar* nucleopolyhedrosis virus and *Entomophaga maimaiga* had the dominant role in the reduction of the gypsy moth density.

The activity of *Lymantrya dispar* NPV was reported at many sites, characterized by the extremely high population size of the gypsy moth. During the growing season in 2011 and 2012, in some forest areas of central Serbia, where the increased mortality rate of the gypsy moth larvae was reported and where there was no significant damage of the foliage caused by the feeding of them, the intensive research of the possible causes of this condition was done.

By field and laboratory studies of the causes of their death, the presence of azygospores and conidiospores of the entomopathogenic fungus *Entomophaga maimaiga* was reported in the dead caterpillars. It have been the first records of this kind is Serbia, i.e. Serbia is the third European country in which this fungus has been reported. In the investigated area, it showed to be a powerful reducer of the population size of the gypsy moth.

GUBAR, *Lymantria dispar* (L.), I NJEGOVI PRIRODNI NEPRIJATELJI U ŠUMAMA CENTRALNE SRBIJE

Mara TABAKOVIĆ-TOŠIĆ

Rezime

Prema literaturnim podacima, u centralnoj Srbiji do danas je utvrđeno ukupno 81 vrsta prirodnih neprijatelja gubara, i to 17 predatora, 49 parazitoia, 10 vrsta koje se ponašaju kao saprofagi i parazitoidi, te 5 patogena. U navedenom broju najzastupljeniji su insekti koji parazitiraju larveni stadijum gubara, a na drugom mestu su predatori jaja i parazitoidi lutki domaćina. Po broju zastupljenih vrsta, najviše je pripadnika redova Hymenoptera (14 vrsta iz familije Ichneumonidae i 11 iz familije Braconidae) i Diptera (13 vrsta iz familije Tachinidae i 8 iz Familije Sarcophagidae). Od predatora gubara, najzastupljenija ja familija Carabidae iz reda Coleoptera.

Tokom dvadesetogodišnjeg istraživačkog perioda u populacijama gubara, uočena je pojačana aktivnost 59 vrsta njegovih prirodnih neprijatelja i to dvadeset jednog predatora, dvadest devet parazitoida, 7 parazitoida ili saprofaga i 2 patogena. Od svih nađenih vrsta, najveću brojnost i najjaču aktivnost su imali predatori *Trombidium holosericeum, Forficula auricularia*, *Silpha quadripunctata*, *Calosoma sycophanta* i pojedine vrste roda *Carabus,* parazitoidi *Oencyrtus kuwanae* i *Anastatus japonicus,* te patogeni *Ld*NPV i *Entomophaga maimaiga*.

U posmatranom periodu, prosečna stopa parazitiranosti jaja u jajnim leglima kretala se od 0,5 do 20%. Najveća pozitivna promena u aktivnosti parazitoida dogodila se tokom druge gradacije, od 3,5% u 2002. do 20% u 2004. godini. Kada je reč o vrstama janih parazitoida dobijenih u laboratorijskim uslovima gajenja jaja gubara, apsolutno dominantan bio je *Oencyrtus kuwanae* (69-100%).

Aktivnost *Lymantrya dispar* NPV je registrovana na većem broju lokaliteta gde je brojnost gubara beležila enormne vrednosti. Tokom vegetacione sezone 2011. I 2012. godine, u pojedinim šumskim područjima centralne Srbije, gde je uočena veća smrtnost larvi gubara i gde nije došlo do značajnijeg oštećivanja lisne mase prouzrokovanog njihovom ishranom, obavljena su intenzivna istraživanja mogućih uzroka ovakvog stanja. Terenskim i laboratorijskim ispitivanjima uzroka smrtnosti starijih larvenih stupnjeva gubara, dokazano je prisustvo azigospora i konidiospora entomopatogene gljive *Entomophaga maimaiga* u uginulim gusenicama. Ovo su bili prvi nalazi ove vrste u Srbiji, odnosno, Srbija je treća zemlja u Evropi u kojoj je ova gljiva registrovana. Na istraživanim lokalitetima se pokazala kao moćan reduktor nivoa populacije gubara.