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Fauna of phloemo-xylophagous insects, their parasitoids and predators on *Ulmus minor* in Serbia

Čedomir Marković[1] & Aleksandar Stojanović[2]

[1]*Belgrade University, Faculty of Forestry, Kneza Višeslava 1, 11000 Belgrade, Serbia; e-mail: markovicc@ptt.rs*
[2]*Natural History Museum, Njegoseva 51, 11000 Belgrade, Serbia; e-mail: aleksandar@nhmbeo.org.yu*

Abstract: The fauna of phloemo-xylophagous insects, their parasitoids and predators was studied on *Ulmus minor* in Serbia. Sixty insect species were recorded, of which 22 species were phloemo-xylophagous insects, 33 species were their parasitoids and 5 species were their predators. Among phloemo-xylophagous insects, the most common and most abundant species were *Scolytus pygmaeus* (59.93%), *Magdalis armigera* (11.79%), *S. multistriatus* (9.24%), *Exocentrus punctipennis* (8.68%), *S. ensifer* (5.48%) and *S. kirschii* (1.28%). The most frequent and most abundant parasitoid was the species *Ecphylus silesiacus* (65.95%). Also, the parasitoids *Dendrosoter protuberans* (7.46%), *Rhaphitelus maculatus* (6.25%), *Cheiropachus quadrum* (5.49%), *Acrocormus semifasciatus* (3.68%), *Entedon ergias* (1.65%), *Spathius rubidus* (1.53%), *Eubazus augustinus* (1.46%) and *Eurytoma morio* (1.37%), were of major importance.

Key words: phloemophagous insects; xylophagous insects; phloemo-xylophagous insects; parasitoids; predators; *Ulmus minor*; Serbia

Introduction

The field elm, *Ulmus minor* Miller, 1786 (Urticales, Ulmaceae), is slowly disappearing from forests in Serbia. Nowadays, old large-diameter elms (40–50 cm) are rare in Serbian forests and younger trees resulting from natural regeneration are subject to mass decline (Stojanović & Marković 2007). The main reason of elm decline is the epidemics of Dutch elm disease caused by the fungus *Ophiostoma ulmi* (Ophiostomatales, Ophiostomataceae). The fungus develops in the vascular tissue of the infested trees, the vessels are plugged which eventually kills the infested trees (Webber & Brasier 1984). The dead trees are very soon colonised by phloemo-xylophagous insects. Some of them (bark beetles *Scolytus ensifer*, *S. kirschii*, *S. laevis*, *S. multistriatus*, *S. pygmaeus*, *S. scolytus*) during their maturation feeding transmit the *O. ulmi* pathogen spores from the infected to healthy trees and thus participate directly in further spreading of infection (Sengonca & Leisse 1984; Webber & Brasier 1984). As the infection spreading intensity, inter alia, depends directly on their abundance and behaviour, they have been studied thoroughly both in Serbia (Maksimovic 1979; Manojlovic 1986a, b; Manojlovic & Sivcev 1995; Marković et al. 1997) and worldwide (Svihra & Koehler 1982; Kirby & Fairhurst 1983; Neumann & Minko 1985; Sacchetti et al. 1990; Webber 1990; Basset et al. 1992; Favaro & Battisti 1993). However, *U. minor* dead trees are also infested by a great number of other phloemo-xylophagous insect species, their parasitoids and predators. Since, in general, they are still little known in Serbia, and as *U. minor* is a species which is increasingly disappearing from our forests, we decided to undertake an in-depth study of the fauna of phloemo-xylophagous insects, their parasitoids and predators on *U. minor*. The aim of this research was: (1) to make a detailed list of phloemo-xylophagous species, their parasitoids and predators on *U. minor* in Serbia; (2) to assess the abundance and incidence of the identified species of phloemo-xylophagous species, their parasitoids and predators. This research was a part of a wider study on the role of insects in the decline of broadleaf tree species in Serbia. For this reason, inter alia, the study results will also be discussed in this sense.

Material and methods

Phloemo-xylophagous insects, their parasitoids and predators were studied over the period 2001–2003 at 8 locations in Serbia: Aleksinac (43°32′ N, 21°42′ E), Beograd – Ada Ciganlija (44°47’ N, 20°24′ E), Beograd – Košutnjak (44°46′ N, 20°25′ E), Beograd – Stepin Gaj (44°44′ N, 20°32′ E), Bojčinska Šuma (44°43′ N, 20°09′ e E), Goč (43°33′ N, 20°53′ E), Kosmaj (44°27′ N, 20°33′ E), Obrenovac – Obrenovački Zabran (44°39′ N, 20°13′ E). At each location, 30–40 cm long cuttings, diameter 1–15 cm, were taken from different parts of *U. minor* branches and stems infested by phloemo-xylophagous insects. A sample consisted of 15 such cuttings. As *U. minor* large-diameter trees are rare in our forests, the samples were taken from the trees of 10–15 cm diameter at breast height since the elms of such diameters are most widespread in our forests. The samples were taken in spring during the emergence of phloemo-

Table 1. The collected insect species, their systematic status, total abundance, total dominance and frequency at the study sites and in the collected samples.

Insect species	N	D	Nsi		Ns	
			n	%	n	%
Phloemo-xylophagous insects						
Coleoptera						
Anobiidae						
Gastrallus laevigatus (Olivier, 1790)	12	0.07	1	12.5	1	4.8
Ptinomorphus regalis (Duftschmid, 1825)	2	0.01	1	12.5	1	4.8
Bostrichidae						
Xylopertha retusa (Olivier, 1790)	23	0.13	2	25.0	2	9.5
Buprestidae						
Anthaxia manca (L., 1767)	24	0.14	6	75.0	7	33.3
A. deaurata (Gmelin, 1790)	1	0.01	1	12.5	1	4.8
Ovalisia mirifica (Mulsant, 1855)	12	0.07	2	25.0	2	9.5
Cerambycidae						
Clytus arietis (L., 1758)	1	0.01	1	12.5	1	4.8
Exocentrus punctipennis Mulsant et Guillebeau, 1856	1504	8.68	8	100.0	12	57.1
Glaphyra umbellatarum (Schreber, 1759)	2	0.01	1	12.5	1	4.8
Leiopus nebulosus (L., 1758)	1	0.01	1	12.5	1	4.8
Neoclytus acuminatus (F., 1775)	14	0.08	2	25.0	3	14.3
Pogonocherus fasciculatus (De Geer, 1775)	1	0.01	1	12.5	1	4.8
Ropalopus macropus (Germar,1824)	3	0.02	2	25.0	2	9.5
Xylotrechus arvicola (Olivier, 1795)	1	0.01	1	12.5	1	4.8
Curculionidae						
Magdalis armigera (Geoffroy, 1785)	2043	11.79	8	100.0	11	52.4
Pteleobius vittatus (F., 1787)	501	2.89	3	37.5	3	14.3
Scolytus ensifer Eichhoff, 1881	949	5.48	4	50.0	6	28.6
S. kirschii Skalitzky, 1876	222	1.28	4	50.0	8	38.1
S. laevis Chapuis, 1869	19	0.11	1	12.5	1	4.8
S. multistriatus (Marsham, 1802)	1601	9.24	4	50.0	8	38.1
S. pygmaeus (F., 1787)	10386	59.93	8	100.0	13	61.9
S. scolytus (F., 1775)	9	0.05	1	12.5	1	4.8
Parasitoids						
Hymenoptera						
Ichneumonidae						
Xorides gracilicornis (Gravenhorst, 1829)	9	0.09	2	25.0	2	9.5
Odontocolon appendiculatum (Gravenhorst, 1829) ?	2	0.02	1	12.5	1	4.8
Dolichomitus sp.	1	0.01	1	12.5	1	4.8
Braconidae						
Coeloides scolyticida Wesmael, 1838	3	0.03	2	25.0	2	9.5
Dendrosoter protuberans (Nees, 1834)	733	7.46	6	75.0	12	57.1
Diospilus intermedius (Foerster, 1878)	36	0.37	2	25.0	2	9.5
Doryctes leucogaster (Nees, 1834)	2	0.02	1	12.5	1	4.8
D. pomarius Reinhard, 1865	91	0.93	2	25.0	3	14.3
D. striatellus (Nees, 1834)	3	0.03	3	37.5	3	14.3
Ecphylus silesiacus (Ratzeburg, 1848)	6483	65.95	8	100.0	18	85.7
Eubazus augustinus (Ruthe, 1867)	144	1.46	7	87.5	12	57.1
Leluthia paradoxa (Picard, 1938)	52	0.53	2	25.0	2	9.5
Spathius phymatodis Fischer, 1966	1	0.01	1	12.5	1	4.8
S. rubidus (Rossi, 1794)	150	1.53	5	62.5	8	38.1
Triaspis obscurella (Nees, 1816)	2	0.02	1	12.5	1	4.8
Eurytomidae						
Eurytoma morio Boheman, 1836	135	1.37	5	62.5	7	33.3
E. nodularis Boheman, 1836	2	0.02	2	25.0	2	9.5
Pteromalidae						
Acrocormus semifasciatus Thomson, 1878	362	3.68	4	50.0	6	28.6
Cerocephala eccoptogastri Masi, 1922	200	2.03	3	37.5	3	14.3
Cheiropachus quadrum (F., 1787)	540	5.49	7	87.5	14	66.7
Cleonymus brevis Boucek, 1972	4	0.04	3	37.5	3	14.3
Dinotiscus aponius (Walker, 1848)	4	0.04	1	12.5	1	4.8
Heydenia pretiosa Foester, 1856	7	0.07	1	12.5	1	4.8
Macromesus amphiretus Walker, 1848	8	0.08	2	25.0	2	9.5
Mesopolobus typographi (Ruschka, 1924)	31	0.32	1	12.5	2	9.5
Nedinotus beogradensis Boucek, 1991	12	0.12	1	12.5	1	4.8
Rhaphitelus maculatus Walker, 1834	614	6.25	5	62.5	9	42.9
Encyrtidae						
Oobius sp.	4	0.04	1	12.5	2	9.5

Table 1. (continued)

Insect species	N	D	Nsi		Ns	
			n	%	n	%
Eulophidae						
Entedon armigerae Graham, 1971	4	0.04	1	12.5	1	4.8
E. ergias Walker,1839	162	1.65	5	62.5	8	38.1
Euderus agrili Boucek, 1963	3	0.03	1	12.5	1	4.8
Tetrastichus ulmi Erdös, 1954	11	0.11	2	25.0	3	14.3
Bethylidae						
Cephalonomia hypobori Kieffer, 1919	15	0.15	2	25.0	3	14.3
Predators						
Coleoptera						
Malachiidae						
Malachius bipustulatus (L., 1758)	2	25.00	1	12.5	1	4.8
Cleridae						
Opilo pallidus (Olivier, 1795)	2	25.00	1	12.5	1	4.8
Thanasimus formicarius (L., 1758)	1	12.50	1	12.5	1	4.8
Tilloidea unifasciata (F., 1787)	1	12.50	1	12.5	1	4.8
Laemophloeidae						
Cryptolestes ferrugineus (Stephens, 1831)	2	25.00	1	12.5	2	9.5

Explanations: N – total number of adult insects; D – total dominance (%); Nsi – number of sites at which the species was identified; Ns – number of samples in which the species was identified; n – number; % – percentage.

Table 2. Number of collected insect adults and species per trophic groups.

Trophic group	N_a				N_{sp}					
	n	%	n_a	SD	n	%	n_{min}	n_{max}	n_a	SD
Phloemo-xylophagous insects	17331	63.79	825.3	±1444.9	22	36.7	1	9	4.1	±2.4
Parasitoids	9830	36.18	468.1	±682.8	33	55.0	2	14	6.6	±3.7
Predators	8	0.03	0.4	±0.9	5	8.3	0	2	0.3	±0.6
$\sum$	27169	100	1293.8	/	60	100	/	/	/	/

Explanations: N_a – number of adults; N_{sp} – number of species; n – total number; n_a – average per sample; n_{min} – minimal number per sample; n_{max}– maximal number per sample; SD – standard deviation; % – percentage.

xylophagous pupae. In the laboratory, the collected samples were placed in emergence boxes, which were kept in the insectarium under field conditions. During the flight of adult phloemo-xylophagous insects, their parasitoids and predators, the emergence boxes were examined daily. The emerged adults were collected, killed by ether, prepared, and identified. The species of the order Coleoptera were identified by Č. Marković and A. Stojanović and those of the order Hymenoptera by A. Stojanović. The adult insects are stored in the collection of the Faculty of Forestry in Belgrade.

Altogether 21 samples were collected. Each insect species obtained from the collected samples was classified according to its trophic level (phloemo-xylophagous species, parasitoid, and predator), after which the significance of each species in the group was assessed based on:

1. Dominance (ratio between the number of adults of a species and the total number of obtained adults in a group, in percents);
2. Number of sites where the species was identified;
3. Number of samples in which the species was identified.

Phloemophagous and xylophagous species are presented together, because some of the obtained species, due to their life history characteristics (they develop both in the xylem and in the phloem), could not be precisely classified.

Results

Altogether 27,169 adult phloemo-xylophagous insects, their parasitoids and predators were obtained from the collected samples. Their identification resulted in 60 species (33 species of the order Hymenoptera and 27 species of the order Coleoptera) (Table 1), of which 22 species were phloemo-xylophagous insects, 33 species were their parasitoids and 5 species were their predators. The greatest number of phloemo-xylophagous species belonged to the families Cerambycidae (8) and Curculionidae (8), parasitoid families were Braconidae (12) and Pteromalidae (10), and predators belonged to the family Cleridae (3). Total number of species in the samples differed highly (3–22). Table 2 presents, per trophic groups, the minimal, maximal and average numbers of the species identified in the study samples.

Regarding the abundance of adults, the most widespread were phloemo-xylophagous insect species (63.79%), their parasitoids (36.18%) and finally their predators (0.03%) (Table 2). The most common and abundant phloemo-xylophagous insect species were *Scolytus pygmaeus, Magdalis armigera* and *Exocen-*

trus punctipennis (Table 1). These three species were recorded at all study sites and they were often found together in the collected samples. In most cases the dominant species was *S. pygmaeus.* It was identified in 61.9% samples. Its dominance in the samples ranged from 3.4 to 100%, mostly (53.8%) from 60 to 100%. *E. punctipennis* was collected from 57.1% of the total sample and *M. armigera* from 52.4%. The dominance of these two species in the samples ranged from 5 to 95%, however, in most samples (*E. punctipennis* 58.3%, *M. armigera* 63.6%) it did not exceed 10%. These species were dominant among phloemo-xylophagous insects in 4 samples each.

In addition to *S. pygmaeus*, *E. punctipennis* and *M. armigera,* frequent phloemo-xylophagous insect species were also *S. multistriatus*, *S. kirschii* and *S. ensifer* (Table 1). In a number of samples (*S. multistriatus* 33%, *S. kirschii* and *S. ensifer* 37.5%), their dominance was high (60–95%). However, in other samples, *S. multistriatus* usually did not exceed 20% and *S. kirschii* and *S. ensifer* 10%. *Anthaxia manca* was also frequent, but its number was always low. The maximal value of its dominance in the samples was 1%. Other recorded phloemo-xylophagous species were rare. Many of them (10) were identified in one sample each.

The most common and by far the most abundant parasitoid species was *Ecphylus silesiacus* (Table 1). Of the total number of the recorded adult parasitoids, the majority (65.95%) belonged to this species. It was recorded in 85.7% samples and in 66.7% it was the dominant parasitoid species. In the study samples from which it was collected, its dominance ranged from 3.2 to 92.4%, mostly (61.1%) from 55 to 92.4%. The parasitoids *Cheiropachus quadrum*, *Eubazus augustinus*, *Dendrosoter protuberans*, *Rhaphitelus maculatus* and *Spathius rubidus* were also frequent, but abundant only in some samples. In the study samples from which they were collected, the dominance of *Ch. quadrum* and *D. protuberans* usually did not exceed 10%, and *E. augustinus*, *Rh. maculatus* and *S. rubidus* did not exceed 5%. However, as it was already noted, there were also some samples in which their dominance was considerably higher. Thus for instance, the dominance of *D. protuberans* in the sample collected at the site Beograd, Ada Ciganlija on 18.04.2001 accounted for 93.6%, and *Rh. maculatus* in the sample collected at the same site on 20.04.2003 accounted for 81.0%.

In addition to the above parasitoid species, the species *Acrocormus semifasciatus*, *Entedon ergias* and *Eurytoma morio* were also frequent, but always in smaller numbers. The dominance of *E. ergias* and *E. morio* did not exceed 10% in any of the samples and *A. semifasciatus* did not exceed 20%. Compared to the above species, other collected parasitoids were rare. However, some parasitoids (*Doryctes pomarius*, *Leluthia paradoxa*, *Cerocephala eccoptogastri*) were more numerous in some samples.

Total number of the collected adult predators was low (5) (Table 1). For this reason, it was not possible to analyse the significance of individual species.

Discussion

The list of 60 insect species collected during this research shows that the number of phloemo-xylophagous insect species, their parasitoids and predators on *Ulmus minor* in Serbia was rather high. Unfortunately, *U. minor*, and also other *Ulmus* species, are slowly disappearing from our forests. For this reason, the foresters often hypothesize whether the extinction of *Ulmus* species in our forests would also imply the disappearance of the associated organisms. However, this is not likely in the case of phloemo-xylophagous insects, their parasitoids and predators on *U. minor,* because the species collected during this research were polyphagous and, in addition to *U. minor,* they were also associated with other tree species (Arnoldi 1965; Rihter & Alekseev 1965; Miksic & Georgijevic 1973; Tobias 1976; Shenefeld 1978; Miksic & Kopric 1985; Pfeffer 1995; Noyes 2003; Kenis et al. 2004; Ilić 2005; Marković & Stojanović 2011). In the case of disappearance or reduction in the percentage of *U. minor* and other *Ulmus* species in our forests, the abundance of some species will probably be reduced, because *Ulmus* species are their main hosts. For example, in the past *S. scolytus* was common and highly abundant on dead trees of *Ulmus* spp. in Serbia. However, since large-diameter elms (40–50 cm), whose large-diameter parts are usually infested by this species (Manojlović 1995), have become rare in our forests, the abundance and incidence of *S. scolytus* decreased considerably. Thus, during our study, this species was identified only once.

Generally in Serbia, *U. minor* trees of dbh from 10 to 15 cm were most often infested by phloemo-xylophagous insects *S. pygmaeus*, *E. punctipennis* and *M. armigera.* In addition, commonly found species were also *S. multistriatus*, *S. kirschii*, *S. ensifer* and *Anthaxia manca.* The dominant species by the abundance of adults was usually *S. pygmaeus.* However, also the abundance of the species *E. punctipennis*, *M. armigera*, *S. multistriatus*, *S. kirschii* and *S. ensifer* can sometimes be very high.

All the mentioned phloemo-xylophagous species are widely distributed in Southern Europe (Arnoldi 1965; Rihter & Alekseev 1965; Miksic & Georgijevic 1973; Miksic & Kopric 1985; Pfeffer 1995; Ilic 2005). As they breed on dead and recently cut wood, their significance in normal conditions in forestry is not high. However, when *Ulmus* trees are infected by the fungus *O. ulmi,* bark beetles *S. ensifer*, *S. kirschii*, *S. multistriatus* and *S. pygmaeus* become highly important, because during maturation feeding their adults transmit *O. ulmi* spores from the infested trees to healthy trees (Weber et al. 1984). Hence, in forests characterised by mass dying of *Ulmus* spp. the abundance of the above bark beetles should be reduced. The great differences in the abundance of *S. pygmaeus* and other bark beetle species recorded in our research are also caused by the small sizes of adults. As a result, *S. pygmaeus* infests also the small-diameter branches (1–2 cm) which, thanks to their thin bark, are not attractive to other species of the collected bark beetles (Svihra & Koehler 1982; Merlin 1984; Manojlovic & Sivcev 1995). The collected sample contained also the small-diameter branches.

Parasitoid fauna of phloemo-xylophagous insects on *U. minor* is very rich in Serbia. Based on the study results, it consists of 33 species. As some of them can parasitize several phloemo-xylophagous species recorded in the same sample (Tobias 1976; Shenefeld 1978; Noyes 2003; Kenis et al. 2004), the study parasitoids were not precisely separated by hosts. Among them, the most abundant and widespread species was *E. silesiacus.* As it was a significant parasitoid of the study bark beetles (Manoljovic et al. 2000; Stojanović & Marković 2007), the high values of its dominance were most likely caused by the high abundance of bark beetles in the collected samples. According to Marković & Stojanović (2011), *E. silesiacus* in Serbia was a dominant parasitoid of phloemo-xylophagous insects also on the branches of *Quercus cerris* L., 1753, *Q. frainetto* Tenore, 1813, *Q. petraea* Mattuschka (Lieblein, 1784), and *Q. robur* L., 1753. Also, it was one of rather significant parasitoids of shothole borer *S. rugulosus* (Müller) (Stojanović & Marković 2001).

In addition to *E. silesiacus,* major parasitoids of phloemo-xylophagous insects on *U. minor* in Serbia were also *A. semifasciatus*, *Ch. quadrum*, *D. protuberans*, *E. augustinus*, *E. ergias*, *E. morio*, *Rh. maculatus* and *S. rubidus.* Although the dominance of the species *Ch. quadrum*, *E. augustinus*, *D. protuberans*, *Rh. maculatus* and *S. rubidus* was high in some samples, generally these, and also other mentioned parasitoid species were not abundant in the majority of the study samples. Most of the above species are, like *E. silesiacus*, well-known parasitoids of bark beetles in Serbia (Manoljovic et al. 2000; Stojanović & Marković 2001, 2007; Marković & Stojanović 2003). As the abundance of bark beetles in the collected samples was high, the above parasitoid species were more abundant compared to other species of the collected parasitoids.

In contrast to parasitoids, the number of the collected predators of phloemo-xylophagous insects was small (5). We are of the opinion that it was partly the result of the applied method, because a number of predators escaped during the sampling and transport of cuttings from the field to the laboratory. As a result, the list of predators of phloemo – xylophagous insects on *U. minor* in Serbia is by no means complete and it should be updated in future. The species in the list are widely distributed predators of phloemo-xylophagous insects in Serbia and also in other parts of Southern Europe (Winkler 1961; Rihter 1965; Kolomiec & Bogdanova 1980; Čapek et al. 1987; Kenis et al. 2004; Jurc et al. 2009; Marković & Stojanović 2011).

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