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POLLINATOR DIVERSITY (HYMENOPTERA AND DIPTERA) IN SEMI-NATURAL HABITATS IN SERBIA DURING SUMMER

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Abstract – The aim of this study was to assess species diversity and population abundance of the two main orders of pollinating insects, Hymenoptera and Diptera. The survey was conducted in 16 grassland fragments within agro-ecosystems in Vojvodina, as well as in surrounding fields with mass-flowering crops. Pollinators were identified and the Shannon-Wiener Diversity Index was used to measure their diversity. Five families, 7 subfamilies, 26 genera and 63 species of insects were recorded. All four big pollinator groups investigated were recorded; hoverflies were the most abundant with 32% of the total number of individuals, followed by wild bees – 29%, honeybees – 23% and bumblebees with 16%.

Key words: Pollinators, Hymenoptera, Diptera, agro-ecosystems, grassland fragments

INTRODUCTION

The importance of biological diversity for ecosystem functioning and services is widely recognized, not only as the basis for processes in nature, but also as a prerequisite for the improvement and sustainability of human wellbeing. Thus, preserving biodiversity is one of the major standpoints of contemporary environmentalists. For this purpose, it is necessary to understand the preconditions for biodiversity maintenance and to predict the effects of biodiversity losses. This requires the study of interspecific interactions, such as that between plants and pollinators (Fründ et al., 2010), and of the variability and abundance of these communities in particular areas. Pollinators have a key part in the survival of terrestrial ecosystem integrity through their major role in plant reproduction, thereby providing services and goods to society, because many of the world's crop plants are dependent upon pollination for their productivity (Potts et al., 2009). Many empirical studies have found positive correlations between pollinator diversity and plant functioning (Perfectti et al., 2009). Pollination by insects and other animals is significant in most terrestrial habitats. It involves 67% of species of flowering plants and a relatively high diversity of insect taxa (Forup et al., 2008). On the other hand, 35% of crop production worldwide (Kremen et al., 2007; Steffan-Dewenter and Westphal, 2008) and 70% of major global crop species rely on animal pollination (Steffan-Dewenter and Westphal, 2008).

A decline in pollinator population abundance and diversity has been registered worldwide. Anthropogenic alterations in climates and habitats have resulted in reductions in the biodiversity of many pollinator families (Biesmeijer et al., 2006). Different factors, abiotic and biotic, influence these parameters in the wild, including predators, competitors, parasites, pathogens and the availability of key resources (Kremen et al., 2007). Research on pollinators has expanded since studies illustrated the effects of habitat fragmentation on the diversity of this group of organisms and addressed the significance of wild pollinators for reproduction of crops (Biesmeijer et al., 2006; Steffan-Dewenter and Westphal, 2008). Namely, the trend of increasing decline in pollinator populations in recent years created concern and drew the attention of experts on a global scale. Human impact has modified the original landscape through degradation, destruction and fragmentation of natural habitats and also through the establishment of new anthropogenic habitats and alterations in pollinator communities which have been closely linked to changes in land-use practices (Kremen et al., 2007). Fragmentation and the loss of natural and semi-natural habitats have been considered a major threat for biodiversity in general (Steffan-Dewenter and Westphal, 2008). Evidence indicates the decline of pollinators around the world and in some countries and regions the trend is that losses are set to continue (Biesmeijer et al., 2006; Potts et al., 2009). In general, species numbers and densities are expected to decline in these conditions, with habitat or food specialists and higher trophic levels being more sensitive to increasing habitat isolation and reduction (Steffan-Dewenter and Westphal, 2008). Parallel diversity reductions in pollinating insects and insect-pollinated flowering plants have been reported, suggesting a functional coupling and dependence between them (Fründ et al., 2010). Plant-visiting insects depend on plant diversity, but a reduction in flower variety may cause decreases in pollinator diversity; thus there are positive correlations between species richness on several scales (Fründ et al., 2010). At first, observations of this pollinator crisis mainly arose from recorded declines of crop-pollinating insects (Carvalheiro et al., 2010). Habitat alteration is definitely the primary cause for this and an agriculture crisis in crops which are pollinator-dependent is likely to occur only in areas where little natural habitat, hence associated insect biodiversity, remains (Carvalheiro et al., 2010).

Agricultural fields have replaced natural landscapes in many regions. In the present study, the focus was on grassland fragments, semi-natural habitats surrounded by areas with economically important crops. These landscapes included uncultivated fragments with vegetation typical for steppe and mesophilic meadow. A continental semi-arid climate and soil of chernozem type are common features for grasslands in temperate regions. The fertile land of these habitats is the main reason for converting these natural landscapes into agricultural fields. Among crops cultivated in this area, sunflower (*Helianthus annuus* L.) is one of the most important and most common. It is valuable for the oil industry throughout the world (Hernández, 2008). Due to its high output of nectar and pollen, it is the main source for honey production among crop plants in this region (Miklič et al., 2005). It has *entomophyllous* androgynous flowers and its yield depends directly on the visits of insects (Miklič et al., 2005; Hernández, 2008). Sunflower genotypes vary in their attractiveness to pollinators (Miklič et al., 2005; Hernández, 2008), but external factors have a greater impact on pollination and fertilization, which influence the secretion of nectar and thus pollinator visits (Miklič et al., 2005). In general, earlier studies were conducted involving research into the pollinators of cultivated plant species in this region because this problem was recognized as important in terms of agriculture. However, little is known about the diversity and abundance of insect pollinators in semi-natural grassland habitats in this area or about their importance for the pollination of surrounding crops. The main conclusion based on previous research in other countries is that it is very important to assess pollinator interaction in the field with cultivated crops, in this case sunflowers, as well as in the semi-natural habitats within agricultural landscapes, in this case grassland fragments.

The focus of this study was on two of the most important groups of pollinators: bees (Hymenoptera) and hoverflies (Diptera). Both managed (honeybees, some bumblebee and some solitary bee species) and wild pollinators (hoverflies, bumblebees and solitary bees) were included in the study, as all these groups contribute to different aspects of the pollination of wild flowers and crops in this region. No previous research regarding this problem has been done in

Serbia, and therefore the main goal was to investigate pollinating species diversity in this area.

MATERIALS AND METHODS

Fieldwork was conducted in 16 semi-natural habitats in Vojvodina, the northern province of Serbia, (45˚N, 19/20˚E) (Fig. 1). Forests and woodland cover comprises less than 7% of the territory of this northern province of Serbia, and nearly 70% is agricultural land. Our study areas were grassland fragments (2-6 ha) within agro-ecosystems, selected by the use of satellite images from the Google Earth program and by field observation. Some of them were mesophilic meadows, some had typical steppe vegetation, and others were ruderal habitats. Therefore, the researched sites have similar climate and soil, but they differ in size, shape and composition, of both the grassland plant species and crop plants that surround them.

Surveys were carried out in June, July and early August 2011, which is the main flowering time in the area and thus the main pollination period of most wild grassland plant species and of sunflowers. This mass flowering crop was in bloom during data collection in areas surrounding some of the surveyed grassland fragments, so it was taken into account in the resulting comparison and discussion. Insect species from four big pollinator groups were observed – hoverflies, honeybees, bumblebees and other wild bees. Pollinator visits were noted on flowers and around them, including grassland plant species of all of the 16 areas investigated, as well as on sunflowers on eight of the agricultural sites selected in a radius of 1 km around eight semi-natural habitats. All observations were carried out between 7 a.m. and 12 a.m., to cover the period of most pollinator activity, because temperature is one of the limiting factors for their activity level. For the same reasons wind and rain were avoided. In total there were 64 surveys, each

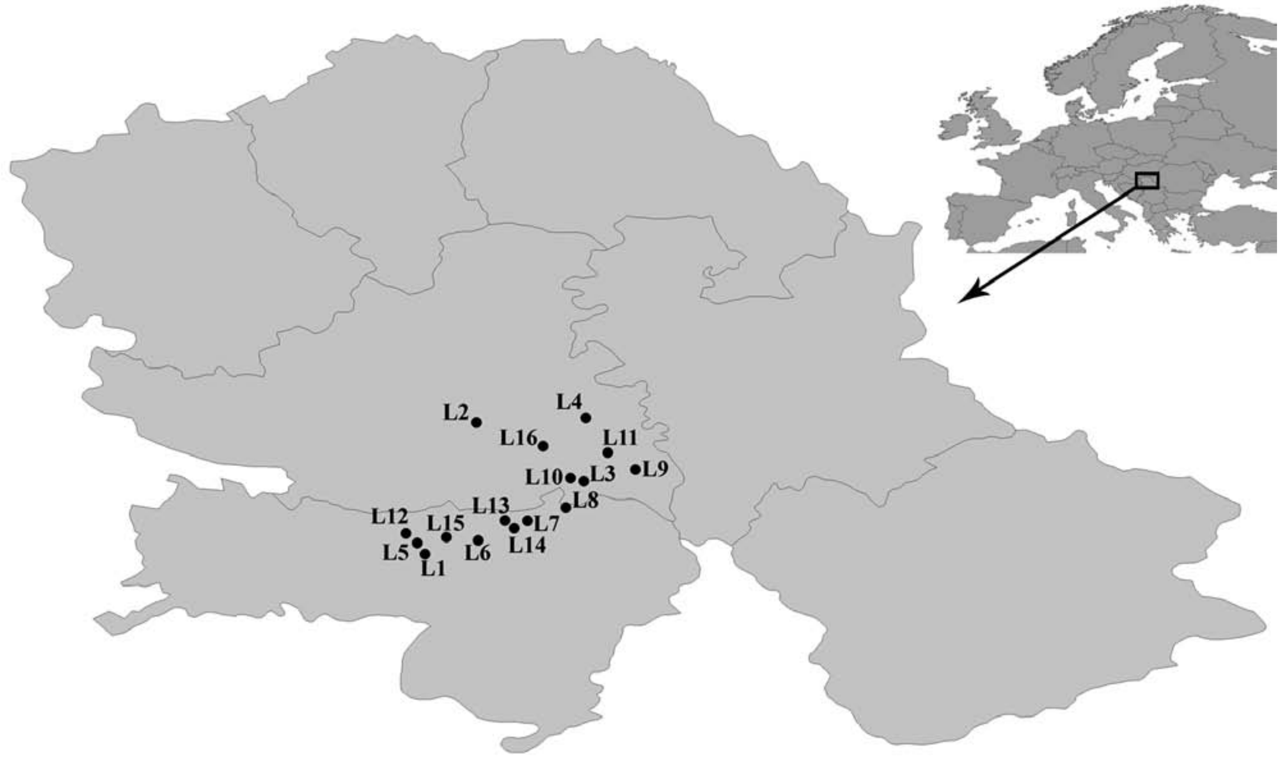

Fig. 1. Map of 16 areas of investigated semi-natural habitats in Vojvodina (Serbia). Marked localities: L1 - Stejanovci, L2 - Čenej, L3 – Kovilj I, L4 - Đurđevo, L5 - Bešenovo, L6 - Rivica, L7 - Krušedol, L8 - Čortanovci, L9 - Vilovo, L10 – Kovilj II, L11 - Šajkaš, L12 - Šuljam, L13 – Neradin I, L14 – Neradin II, L15 - Jazak and L16 – Budisava.

Table 1. All recorded taxa of pollinators in the 16 investigated areas (grassland fragments within agro-ecosystems) in Vojvodina. Table shows numbers of noted individuals per species for every locality (or '-' where species is not found).

Fam.	Species	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16
Andrenidae	*Andrena flavipes* Panzer, 1799	-	1	20	-	-	-	-	2	-	1	33	3	-	2	6	-
	A. hattorfiana Fabricius, 1775	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
	A. ovatula Kirby, 1802	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
	A. fulvago Christ, 1791	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
	A. polita Smith, 1847	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	A. nugeri Mavromoustakis, 1952	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
	A. nitidiuscula Schench, 1853	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
	A. rosae Panzer, 1801	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
	A. nasuta Giraud, 1863	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
	Melitturga clavicornis Latreille, 1806	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-
	Camptopoeum frontale Fabricius, 1804	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Halictidae	*Halictus quadricinctus* Fabricius, 1776	-	-	-	-	-	2	-	-	1	-	-	-	-	-	1	-
	H. eurygnathus – simplex Blüthgen, 1923	7	1	1	5	-	1	-	10	-	4	2	-	-	1	3	11
	H. patellatus Marawitz, 1873	1	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-
	H. subauratus Rossi, 1792	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-
	H. maculatus Smith, 1848	2	1	1	-	2	-	-	-	-	-	-	-	-	-	-	-
	H. semitectus Marawitz, 1874	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
	H. kessleri Bramson, 1879	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
	H. pollinosus Sichel, 1860	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lasioglossum pauxilum Schenck, 1853	15	93	3	14	16	1	7	4	1	56	11	17	44	31	72	69
	L. albipes Fabricius, 1781	1	1	-	-	-	1	-	-	-	-	-	-	-	1	-	-
	L. malachurum Kirby, 1802	-	30	-	-	1	-	-	-	-	-	-	31	5	-	-	-
	L. glabriusculum Marawitz, 1872	1	-	-	-	-	-	-	1	-	-	2	-	-	-	-	-
	L. leucoronium Schrank, 1853	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-
	L. discum Smith, 1853	6	-	2	2	9	-	-	3	-	-	-	-	-	1	-	2
	L. lativentre Schenck, 1853	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
	Nomia (Pseudapis) diversipes Latreille, 1806	1	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-
	Rophites quinquespinosus Spinola, 1808	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
	Rhopitoides canus Eversmann,1852	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
	Sphecodes alternates Smith, 1853	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Amegilla quadrifasciata Villers, 1789	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Apidae	*Eucera clypeata* Erichson, 1835	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-
	Tetralonia nana Marawitz, 1874	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	T. alticincta Lepeletier, 1841	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
	T. scabiosae Mocsáry, 1879	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
	T. lyncea Mocsáry, 1879	-	-	-	-	1	-	-	-	-	-	-	-	-	5	-	-
	Ceratina nigrolabiata Friese, 1896	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
	Apis melifera Linnaeus, 1758	16	44	24	21	22	11	33	25	10	16	21	32	71	84	25	102
	Bombus terrestris Linnaeus, 1758	9	1	30	10	41	20	6	4	-	2	2	13	7	8	14	186
	B. sylvarum Linnaeus, 1761	8	-	-	-	7	2	-	-	-	-	-	-	-	-	-	3
	B. pascuorum Scopoli, 1763	1	-	-	-	1	-	-	-	-	-	-	-	-	1	-	1
	B. ruderarius Müller, 1776	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
	B.gersta eckeri Marawitz, 1882	-	-	-	-	-	-	3	-	-	-	-	-	-	1	-	2
	B. hypnorum Linnaeus, 1758	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-
	B. lapidarius Linnaeus, 1758	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	11
	B. humilis Ylliger, 1806	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
	Osmia spinulosa Kirby, 1802	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Megachilidae	*O. aurulenta* Panzer, 1799	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-
	Heriades crenulatus Nylaneler,1856	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
	Lithurgus cornutus Fabricius, 1787	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
	Anthidium mamicatum Linnaeus, 1758	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
	Megachile albisecta Klug, 1817	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
	M. ericetomus Lepeletier, 1841	11	-	-	-	1	1	-	2	-	-	-	-	8	-	-	2
	M. apicalis Spinola, 1808	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	M. pilideus Alfken, 1924	2	-	-	1	-	-	-	-	10	-	-	-	-	-	-	-
	Syritta pipiens Linnaeus, 1758	3	10	16	8	5	5	20	10	3	35	9	-	6	8	4	1
Syrphidae	*S. flaviventris* Macquart, 1842	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
	Eristalis tenax Linnaeus, 1758	7	10	43	17	12	4	32	19	-	21	17	4	30	-	-	11
	E. arbustorum Linnaeus, 1758	3	1	13	9	6	-	23	6	-	5	-	-	1	5	-	-
	Eristalinus sepulcharis Linnaeus, 1758	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
	Episyrphus balteatus De Geer, 1776	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
	Sphaerophoria scripta Linnaeus, 1758	7	24	41	30	10	4	20	65	7	30	24	7	15	7	7	8
	Xanthogramma pedissequm Harris, 1776	-	-	-	-	-	-	-	-	-	9	-	-	-	-	2	-

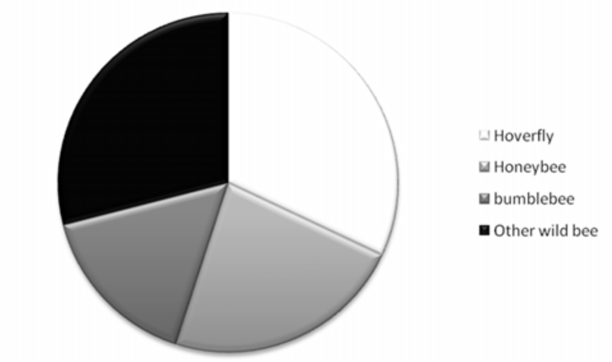

Fig. 2. Representation of four big groups of pollinators in total sample, recorded in investigated semi-natural habitats.

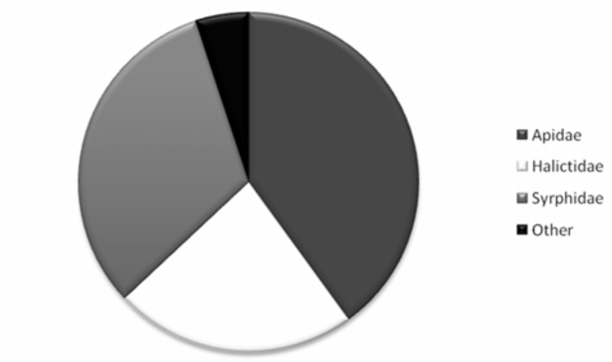

Fig. 3. Representation of families of pollinating insects in total sample, recorded in investigated semi-natural habitats.

Table 2. Percentage of four big groups of pollinators investigated and of families of pollinating insects recorded in total sample.

	Pollinator grups				Families			
	Hoverfly	Wild bee	Honeybee	Bumblebee	Apidae	Syrphidae	Halictidae	Other
%	32	29	23	16	40	32	23	5

of the 16 sites was sampled four times. Field experiments were carried out in approximately the same weather and other changeable conditions to minimize the impacts of environmental heterogeneity on pollinator behavior. Flower-visit data was recorded while walking a transect within the site which was selected based on the richness of flower resources, and thereby source of the pollen. During each observation period, which was one hour on every site, the number and identity of every flower visit from the studied groups was noted. All insects were identified to species level, most of them in the field, and some were captured using a net and transported in vials to the laboratory where they were kept frozen until use. No hoverflies, honeybees or bumblebee queens were collected. The captured specimens are deposited in the Department of Biology and Ecology, University of Novi Sad (Serbia).

The pollinator diversity of each particular area investigated was measured using the Shannon-Wiener Diversity Index (Shannon, 1948). The following equation:

$$H = -\sum P_i(lnP_i)$$

was used, where H represents the index of species diversity in a given locality and P_i is the proportion of the total sample belonging to the ith species.

RESULTS

Insects from both of the main orders of pollinators observed, Hymenoptera and Diptera, were recorded, so all four big pollinator groups were investigated (hoverflies, honeybees, bumblebees and other wild bees). In total, there were 5 families, 7 subfamilies, 26 genera and 63 species of insects in semi-natural habitats of the investigated grassland fragments (Table 1). Regarding pollinator groups (Fig. 2), hoverflies were the most abundant, followed by wild bees, honeybees and finally bumblebees (Table 2). The most numerous, in terms of number of individuals counted, was the family Apidae (Fig. 3), followed by Syrphidae and Halictidae (Table 2). A further two families, Andrenidae and Megachilidae, participated together with only 5% (Fig. 3). The family Halictidae

Table 3. Codes, names and coordinates of the investigated localities, with Shannon-Wiener Diversity Index (H) (Shannon, 1948), number of species per locality (S) and number of individuals per locality (N).

Locality code	Locality name	Coordinates	H	S	N
L1	Stejanovci	45°02’55.67” N 19°43’09.10” E	2.653	21	107
L2	Čenej	45°20’18.07” N 19°49’ 55.75” E	2.122	15	220
L3	Kovilj I	45°12’30.56” N 20°04’05.52” E	2.081	16	200
L4	Đuđevo	45°20’54.24” N 20°04’21.03” E	2.078	14	122
L5	Bešenovo	45°04’24.11” N 19°42’08.49” E	2.076	15	135
L6	Rivica	45°04’43.05” N 19°50’09.50” E	2.052	13	55
L7	Krušedol	45°07’19.24” N 19°56’40.26” E	1.955	15	154
L8	Čortanovci	45°09’02.71” N 20°01’43.22” E	1.867	16	156
L9	Vilovo	45°14’05.26” N 20°10’53.94” E	1.861	10	42
L10	Kovilj II	45°12’55.87” N 20°02’20.67” E	1.850	13	182
L11	Šajkaš	45°16’17.96” N 20°07’13.98” E	1.833	11	123
L12	Šuljam	45°05’38.51” N 19°40’38.21” E	1.695	8	108
L13	Neradin I	45°07’21.26” N 19°53’42.57” E	1.692	9	187
L14	Neradin II	45°06’20.13” N 19°54’54.84” E	1.603	17	159
L15	Jazak	45°05’09.50” N 19°45’59.31” E	1.485	14	143
L16	Budisava	45°17’08.61” N 19°58’42.81” E	1.478	16	413

Table 4. Taxa of pollinators recorded in agro-ecosystems, fields with mass flowering crop – sunflower, surrounding investigated grassland fragments (L1 - L3, L9 - L11, L13 and L15).

subfamilia	genus	species	L1	L2	L3	L9	L10	L11	L13	L15
Halictinae	*Lasioglossum*	*pauxillum*					1			
Megachilinae	*Megachille*	apicalis	2							
	Apis	*melifera*	48	153	44	40	72	38	161	34
Apinae	Bombus	terrestris	19	25	12	15	11	18	29	62
		hypnorum					1			
Syrphinae	*Sphaerophoria*	*scripta*					1			
Eristalinae	*Eristalis*	*tenax*	2	13	3	3		1	5	6
		arbustorum		1						

was represented with the highest number of species (19), followed by Apidae (16) and Andrenidae (11).

Three species were found in all researched sites (L1-L16) (Table 1): *Apis mellifera* (Apinae), *Sphaerophoria scripta* (Syrphinae) and *Lasioglossum pauxilum* (Halictinae); two were noted on almost all of the studied localities: *Bombus terrestris* (Apinae) (all except L9) and *Syritta pipiens* (Eristalinae) (all except L12). More than 50% of the species were found only on one of the sites each: Andreninae: *Andrena hattorfiana* (L9), *A. ovatula* (L4), *A. fulvago* (L10), *A. polita* (L2), *A. nugeri* (L4), *A. nitidiuscula* (L7), *A. rosae* (L14), *A. nasuta* (L3), *Melitturga clavicornis* (L9), *Camptopoeum frontale* (L12); Halictinae: *Halictus semitectus* (L4), *H. kessleri* (L15), *H. pollinosus* (L3), *Lasioglossum lativentre* (L10), *Rophites quinquespinosus* (L8), *Rhopitoides canus* (L7), *Sphecodes alternatus* (L2); Anthophorinae: *Amegilla quadrifasciata* (L6), *Tetralonia nana* (L1), *T. alticincta* (L11), *T. scabiosae* (L15), *Ceratina nigrolabiata* (L15); Apinae: *Bombus humilis* (L16); Megachilinae: *Osmia spinulosa* (L8), *O. aurulenta* (L7), *Heriades crenulatus* (L8), *Lithurgus cornutus* (L5), *Anthidium manicatum* (L14), *Megachile albisecta* (L9); Eristalinae: *Syritta flaviventris* (L3), *Eristalinus sepulchralis* (L3); and Syrphinae: *Episyrphus balteatus* (L10). All other species were found in several researched sites (Table 1).

The Shannon-Wiener Diversity Index, H, was calculated for every locality L1-L16 (Table 3). Stejanovci (L1) was the site with the highest, and Budisava (L16) the site with the lowest index value. According to these measurements, values ranged from 1.478 to 2.653 (Table 3), which is just around the middle, because the Shannon-Wiener Diversity Index can vary between 0 and 4.6 when using the natural log (ln), as in this case. The average number of species per site was 14, ranging from 8 in Šuljam (L12) to 21 in Stejanovci (L1), and the number of recorded individuals ranged from 42 in Vilovo (L9) to 413 in Budisava (L16), with an average value of 157. The total number of individuals noted in all 16 localities was 2506.

Pollinator species were also identified and counted in eight agricultural sites with the mass-flowering crop, sunflower (Table 4). Insects from all four observed big pollinator groups (hoverflies, honeybees, bumblebees and other wild bees) were recorded. Honeybees were the most dominant, represented by *Apis mellifera*, with 72% of all counted individuals. They were followed by bumblebees, *Bombus terrestris* – 23% and hoverflies – the most numerous was *Eristalis tenax* with 4%. All the other five recorded species (*Lasioglossum pauxilum, Megachile apicalis, Bombus hypnorum, Sphaerophoria scripta* and *Eristalis arbustorum*) participated together with only 1% of the total number of noted specimens.

DISCUSSION

Pollinator diversity varies between habitats, both in species richness and in the total number of individuals recorded. Shannon-Wiener Diversity Index (S-W index) values ranged from 1.478 (L16) to 2.653 (L1) (Table 3), and for calculations with natural log (ln) in equations, index values can range from 0 to 4.6. Therefore, values in the middle, as in this case, indicate that the numbers of individuals are not evenly distributed between all the species (values near 4.6), but also that not every species in the sample is the same (values near 0). However, these measures provide a possibility to compare diversity among localities and to draw conclusions. It could be expected that site Budisava (L16) would have the lowest S-W index, because it is represented by a small isolated grassland fragment, ruderal habitat with weed species. There are not many mass-flowering crops in the surrounding area and this particular habitat is dominated by *Cardus acanthoides* L. (Asteraceae) communities, which are probably the greatest source of pollen in the area. Therefore, *Bombus terrestris* (45% of all specimens recorded) and *Apis mellifera* (25%) constitute the vast majority of this pollinator community. Jazak (L15) also had a comparable low value of S-W index that could be explained by the specific characteristics of this steppe locality, grazing and mowing, which are not present in the other studied sites. Stejanovci (L1) is the site with the highest value of S-W index; it is a mesophilic meadow surrounded by fields with mass-flowering crops. It is followed by

L2 and L3, ruderal habitats near agricultural landscapes. The average numbers of species and of individuals per site did not differ in semi-natural habitats regardless of whether there were agricultural fields close by or not, so it could be concluded that in this case the vicinity of crop plants was not affecting the diversity or abundance of plant pollinators of grassland fragment communities. Nevertheless, cultivated plants probably attract pollinators and at the same time a spillover of species of pollinators is possible among these semi-natural habitats and surrounding agro-ecosystems, and therefore the high values of S-W index could be linked to this phenomenon. Other localities were also grasslands, steppes and mesophilic meadows, with a similar environment but somewhat different in size, shape and vegetation composition, of both the wild plant species and crop plants which surround them.

The most numerous family of pollinating insects in all investigated localities was Apidae, followed by Syrphidae and Halictidae. The family Halictidae comprised the highest number of species, followed by Apidae and Andrenidae. More than a half of the species were found only on one of the sites each. Only three species were found in all the researched localities. Observing all the recorded taxa in all of the studied semi-natural habitats it could be concluded that the biodiversity of these grassland fragments is still quite high. Previous research confirmed that flower variety across sites and diversity of visiting insects are positively correlated on a regional scale (Kremen et al., 2007; Fründ et al., 2010). Different ecological mechanisms, such as behavioral interactions among pollinators, play a role in explaining this complicated relation; however, the local floral density is the main factor for it and probably has the most important influence on pollinator activity (Hegland et al., 2009; Perfectti et al., 2009). Yet the impact that changes in plant communities have on insects depends on the level of specialization of pollinators in relation to the flowers they visit. Both large groups of pollinators investigated in this study, Hymenoptera and Diptera, use floral pollen and nectar, but while specialization in flower use is known for only several bee species, most of the other bee and hoverfly species are often regarded as generalists (Fründ et al., 2010). In general, many pollinator taxa visit more than one plant species; generalization is the most common pattern, one-to-one links are rare in plant-pollinator relations and could be caused by temporal or spatial variation in population densities of particular pollinator species or by changes in plant community (Lázaro et al., 2009; Perfectti et al., 2009), which is more likely to happen in conditions of altered environment.

An assessment of the complicated structure of interactions on a plant-pollinator level is essential, especially in terms of reported pollinator declines affected by anthropogenic influences, and some studies have reported that variation in the density and diversity of plant communities surrounding an investigated area could affect both species variability and the composition of pollinators of particular plant species in a given area (Bosch et al., 2009; Lázaro et al., 2009). Assumptions have been made that mass-flowering crop species could outcompete populations of wild plants for pollinators (Steffan-Dewenter and Westphal, 2008) and that the dispersal ability of wild flower visitors limits their abundance in agricultural fields (Carvalheiro et al., 2010). On the other hand, there are studies showing that pollinator abundance and diversity could be higher in agricultural than in some natural habitats and that proximity to agriculture can boost pollinator richness and abundance in natural habitat fragments, possibly due to the floral resources provided in agricultural areas (Kremen et al., 2007). These positive effects may occur in regions where agriculture increases rather than decreases the heterogeneity of the habitat within the foraging bees' range, with characteristics such as mixed crops within or between fields, small field sizes, patches of non-crop vegetation etc. and it has been considered that some crops, such as sunflowers, which provide large amounts of pollen and nectar, can help support some bees and other pollinators at the site level, in the short term (Kremen et al., 2007).

When comparing pollinator situations in fields with mass-flowering crops with those in the semi-natural habitats studied here, some basic conclusions could be reached. Namely, the average number of species and of individuals per study area is smaller in sites with sunflowers. In addition, with regards to different taxonomic categories, there are less families and subfamilies, and no new genera or species with respect to grassland fragments. All of this was to be expected due to the large differences in plant species diversity. There are representatives of both of the main pollinator orders, Hymenoptera and Diptera, in sunflower fields, with the family Apidae being by far the largest, representing 95% of the total number of recorded plant-visiting insects. *Apis mellifera*, the most numerous among all pollinator species in semi-natural habitats (23% of all recorded individuals), contributed much more in sunflower fields (72%) and was presented with even higher numbers of noted individuals. Such results coincide with previous studies on pollinators visiting sunflowers. Miklič et al. (2005) concluded that *Apis mellifera* is the most important pollinators in this region, with the highest proportion of 50-90%, and that it is followed by bumblebees and hoverflies. Therefore, results in this study were similar to previous ones. Commercially managed pollinator species may influence both pollinator and plant communities through mutualistic and competitive mechanisms; however, the abundances and distributions of commercial pollinators may be driven by economic forces, such as market demand for the services of pollinators by growers, and the price of hive products (Kremen et al., 2007).

Major threats for pollinators were distinguished: fragmentation and destruction of natural and semi-natural habitats as a cause of reduction in species richness and abundance, and changes in pollinator species composition. Biodiversity within agricultural landscapes has declined in recent decades in many regions through habitat fragmentation and, in some cases, intensification of agricultural practices and there is an increasing concern that the loss of biological diversity could have harmful consequences for the functioning of ecosystems and that ecosystem services, such as pollination, may be negatively affected even before their dependence on the faunal component is completely understood (Albrecht et al., 2007). These threats are linked to original habitats providing pollinators for crops, potentially impacting plant-pollinator relations, and isolated and small populations in natural and semi-natural habitats (Steffan-Dewenter and Westphal, 2008). In the study of Albrecht et al. (2007), they showed that there is a feedback loop, i.e. plant diversity - pollinator abundance/ richness - plant reproduction - plant diversity. The quality of semi-natural habitats, in terms of plant species richness rather than size, is important in maintaining both pollinator communities and pollination services to plants, both wild species and commercially important crops (Albrecht et al., 2007; Perfectti et al., 2009). Landscape structure is altered by land-use changes that consequently affect the distribution of resources, flora and nesting, changing community composition, population dynamics and the individual behavior of pollinators. Thus, bees follow corridors of vegetation in their search for nectar or pollen sources they avoiding edges created by roads (Kremen et al., 2007). The manipulation of plant communities in terms of creating corridors that connect isolated fragments of semi-natural habitats is probably the best management tool in the conservation of pollinator services within agricultural ecosystems, and pollination is also valuable in ecological restoration projects as a functional bio-indicator for comparing restored to reference communities (Kremen et al., 2007; Forup et al., 2008; Steffan-Dewenter and Westphal, 2008). In order to preserve the remaining fragments of semi-natural habitats it is important to determine the current status of their biodiversity as well as to understand potential changes and trends.

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