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Diversity and Structure of Hoverfly (Diptera: Syrphidae) Communities in Agricultural Areas in Vojvodina Province (Serbia) A Case Study on *Brassica napus* L.

Marina JANKOVIĆ[1]* Marija MILIČIĆ[2] Zorica NEDELJKOVIĆ[3]
Željko MILOVAC[4] Jelena AČANSKI[5] Ante VUJIĆ[1]

[1,6]Department of Biology and Ecology, Faculty of Sciences, University of Novi Sad, Novi Sad, SERBIA
[2,3,5] BioSense Institute Research Institute for Information Technologies in Biosystems, University of Novi Sad, Trg Dr Zorana Đinđića 1, 21000 Novi Sad, SERBIA
[4]Institute of Field and Vegetable Crops, Novi Sad, SERBIA
e-mails: *marina.jankovic.2904@gmail.com, marija.milicic@biosense.rs, zoricaned14@gmail.com, zeljko.milovac@ifvcns.ns.ac.rs, acanskijelena@gmail.com, ante.vujic@dbe.uns.ac.rs
ORCID IDs: [1]0000-0002-2136-815X, [2]0000-0002-3154-660X, [3]0000-0001-7645-4453, [4]0000-0002-6152-6538, [5]0000-0003-1745-6410, [6]0000-0002-8819-8079

ABSTRACT

To gain some insight into the structure of the hoverfly community in fields of oilseed rape (*Brassica napus* L.), we conducted field experiments over three years (2011-2013) at two localities in the province of Vojvodina, northern Serbia. We recorded a total of 20 hoverfly species. Three species-*Episyrphus balteatus* (De Geer, 1776)*,* *Eristalis tenax* (Linnaeus, 1758) and *Eupeodes corollae* (Fabricius, 1794)-were the most abundant in both localities and in each year. In order to determine the effect of climatic and non-climatic parameters on abundance and diversity of hoverflies, two separate PCA analyses were carried out. Multiple linear regressions were used to examine the relationships between abundance and extracted PC axes, while ordinal multinomial regressions were conducted to determine the relationships between species diversity and extracted PC axes. We did not detect statistically significant correlations between climatic and non-climatic parameters and overall hoverfly abundance. PC axes exhibited slight correlation with species diversity. The first PC axis clearly showed that overall species diversity increases with increasing temperature, relative humidity and diversity of crops surrounding the surveyed plots, whereas PC2 related species composition with monthly average rainfall and the season and year of observation. Synecological analysis of our data indicated that only a few species are major contributors to hoverfly communities on the oilseed rape crops we investigated. However, the importance of less abundant hoverfly species should not be underestimated, as sometimes these species play an important role in pollination in a specific part of the day or season, and this should be considered when creating agricultural policies and regulations, especially when it is known that abundances of hoverflies and pollinators in general are positively correlated with floral abundance and abundance flowering plant species.

Key words: Hoverflies, oilseed rape, PCA, pollinators, species diversity, synecological analysis.

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INTRODUCTION

Pollinators contribute to the sustainability and stability of ecosystems. Additionaly, ecosystem services, such as pollination, are immensely important for human prosperity. alarming declines in some pollinator groups, such as bees (Hymenoptera: Apidae), have been reported worldwide (Westrich, 1989; Buchmann & Nabhan, 1997; Allen-Wardell et al, 1998; Bacandritsos et al, 2010; Genersch et al, 2010; Potts et al, 2010a, b). Understanding the consequences of these declines has become a priority, not only because of the biodiversity loss, but also for their considerable impact on agriculture and economy (Costanza et al, 1997). About 70% of tropical crops have at least one variety that is dependent on animal pollination (Roubik, 1995). This figure is even greater for European crops, 84% of which rely on animal pollination at least to some extent (Williams, 1994).

In the U.K. and Netherlands, declining wild plant diversity is mirrored by a decline in wild bee populations, whereas this pattern was not found for hoverflies (Biesmeijer et al, 2006). Although traditionally placed in the pollinator guild and sometimes considered the second most important pollinators after wild bees (Larson, Kevan, & Inouye, 2001), hoverflies have not received much attention as such. For example, *E. tenax* (Linnaeus, 1758) has been suggested as an adequate pollinator for sweet pepper in greenhouses (Jarlan, de Oliveira, & Gingras, 1997) and for apple trees (Kendall, Wilson, Guttridge, & Anderson, 1971), but the efficiency of other hoverfly species regarding pollination of other plants and especially crops has not been assessed properly (Larson et al*,* 2001).

Hoverflies are a diverse group, with over 6000 species described to date (Thompson, 2013). Hoverflies include generalist and cosmopolitan species due to having different larval feeding types and the heterogeneous ecological requirements of adults (Vujić et al*,* 2002), occurring in various habitat types from seashores to mountains. This insect group is not only important because of its role in pollination, the larvae of many species are aphidophagous and can be used in biological control, but only few species are commercially bred for that purposes (Pineda & Marcos-García, 2008).

Brassica napus (common names: rapeseed, rape, oilseed rape) is a member of the family *Brassicaceae*. It has entomophilous flowers capable of both self- and cross-pollination. The open corollas of the flowers allow almost every group of pollinating insects to feed on it, and their yellow colour and the shallow, visible placement of nectar attracts bees, flies and butterflies (Kunin, 1993). Production of oilseed rape has rapidly increased in recent decades (Rathke, Behrens, & Diepenbrock, 2006). It has become the dominant flowering crop in the European Union, mostly as a result of increased demand for energy crops (van der Velde, Bouraoui, & Aloe, 2009). Due to the high oil and protein content of its seeds, oilseed rape is mainly grown for the production of vegetable oil for human consumption, as an animal food and for the production of biodiesel (Milošević et al, 2016). The area under this important crop in Serbia increased from 17860 ha in 2015 to 37500 ha in 2016 (Association for the Promotion of Production and Exports of Grains and Oilseeds, 2017).

Serbia's northern province, Vojvodina, is composed mainly of agricultural land (83%), almost half of which is high quality chernozem soil (Hadžić, Nešić, & Sekulić*,* 2005). This province therefore represents one of the most fertile areas in Serbia. The majority of the region's agriculture is focused on the production of cereal grains, constituting 66% of all crops, but oilseed crops have increased in the past decade (Gligorov et al*,* 2010). As a result of shifting production, Vojvodina now produces 96% of the oilseed crop in Serbia (Gligorov et al*,* 2010). Considering its great economic value, we assessed the composition of hoverfly community found in *B. napus* fields. We investigated two different localities with oilseed crops in Vojvodina (Crvenka and Rimski Šančevi), considering them as a case study for this region, in order to: 1) detect species of hoverflies found on oilseed rape crops; 2) determine the structure of established hoverfly communities; 3) examine the possible influence of climatic and non-climatic parameters on those communities and 4) gain as much information about these species and their relationship to oilseed crops in order to complement the existing knowledge, which would contribute to better management practice.

MATERIAL AND METHODS

Two study areas were chosen to assess hoverfly diversity, one in the central part of Vojvodina at Rimski Šančevi, (Fig. 1A: ▲) and another in its northwestern part, in the agricultural district of Crvenka (Fig. 1A: ●). Both sampling locations are experimental fields of the Institute of Field and Vegetable Crops, Novi Sad. Sampling was carried out between 2011 and 2013. Specimens were collected in spring (from late February/ early March to July), and in the autumn (from September to November).

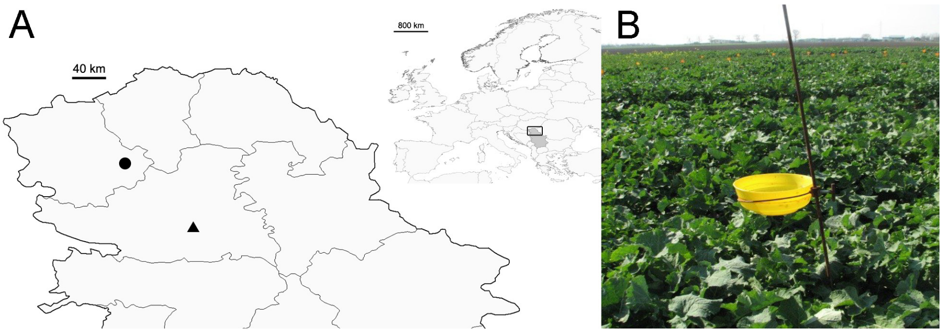

Fig. 1. A. Map of Vojvodina province (northern Serbia) with the sampling locations: ● Crvenka, ▲ Rimski Šančevi. B. Example of a yellow pan trap used for capturing pollinators in fields of *Brassica napus.*

Sampling was carried out using yellow pan traps details in (Leong & Thorp, 1999). The advantage of these traps is that they are easy to use, and the data collected is independent of the weather conditions at the moment of sampling. A set of four traps was placed at each locality. The traps were set on stands, about 10 cm above crop level to prevent overshadowing by the plants (Fig. 1B). Specimens were collected every seven days, stored in 75% ethyl-alcohol and labelled (locality, date, trap number, etc.). Examination of material and species determination was conducted in the

Laboratory for Biodiversity Research and Conservation of the Department of Biology and Ecology, Faculty of Sciences, University of Novi Sad, by Zorica Nedeljković. All specimens were identified to species level, except for three individuals of the genus *Cheilosia* Meigen, 1822, that could not be identified due to damage of taxonomically important characters. We used Van Veen (2004) and Bartsch, Binkiewicz, Rådén, & Nasibov (2009) to aid identifications based on morphological characters. Specimens were examined using a Nikon SMZ 745T binocular microscope.

Assessment of ecological indices

We conducted synecological analysis on our data to detect changes in community structure between seasons and to determine the position of each species in the local assemblages. The indices used here can be divided into analytical ecological indices (abundance, dominance, constancy) and the synthetic index of ecological significance (Grall & Coic, 2005).

Abundance (A) represents the number of specimens collected from a particular species. Species constancy (C_A) represents the percentage of samples in which a particular species occurs and is calculated according to the formula:

$$C_A=(N_P A/N_P)*100$$

Where $N_P A$ is number of samples in which species A occurs and N_P is the total number of samples (Grall & Coic 2005). There are four classes of constancy: C_1 (1-25%)-accidental species; C_2 (25-50%)-accessory species; C_3 (50-75%)-constant species; C_4 (75-100%)-euconstant species.

Dominance reveals the degree to which each species contributes to biomass production in biocenosis and is indicative of relative abundance (Grall & Coic, 2005). Species dominance can be calculated according to the formula:

$$D_A=(N_A/N_1)*100$$

Where N_A is total number of individuals of a particular species, and N_1 is the total number of individuals of all species. Species can be divided into five categories of dominance: D1 (<1%)-subrecedent, D2 (1-2%)-recedent, D3 (2-5%)-subdominant, D4 (5-10%)-dominant, D5 (>10%)-eudominant.

The index of ecological significance (W) represents the relationship between the structural and productive indicators, showing more clearly the position/importance of each species in the assemblage. We calculated the ecological significance index according to the formula:

$$W_A=(C_A*D_A)*100/10000$$

Where C_A is the constancy of species A, and D_A is the dominance of species A. There are five categories of ecological significance: W1 (<0.1%)-accidental species, W2 (0.1-1%)-accessory species, W3 (1-5%)-accompanying species, W4 (5-7%)-constant species, W5 (>10%)-edifying species (Grall & Coic, 2005). Calculation of ecological indices was done using Microsoft Office Excel.

We also calculated the Shannon-Wiener (H') index according to the formula:

$$H'=-\sum p_i \ln p_i$$

Where pi is the proportion of individuals belonging to a certain species in the dataset.

The H' index accounts for both species abundance and evenness. Values of this index range from 0 to 4, with the index increasing as both richness and evenness of the community increases and higher values indicating that richness is evenly distributed among species.

Variation in the abundance and composition of hoverfly species

Climatic variables were represented as monthly averages for temperature, relative humidity, insolation, cloudiness/cloud cover, rainfall, and wind velocity. This information was obtained from the Meteorological Yearbook for each year of our research, available from the Hydrometeorological Service of the Republic of Serbia (RHMZ, 2011-2013). Non-climatic parameters included season (spring and autumn), year of observation, sampling locality and crop diversity around the sampling locality.

The influence of both climatic and non-climatic variables on species diversity and abundance was assessed by principal component analysis (PCA) to reduce observed variables into a smaller number of principal components (PC axes) accounting for most of the variance. PCA was carried out by applying a normal varimax rotation of factor loadings. PCs with eigenvalues >1 were retained as predictor variables. Variables with factor loadings >0.8 were interpreted as meaningfully correlated with the PC axes. PCA analysis was carried out in Statistica (StatSoft, Inc. v. 13.2).

In order to examine the effect of interacting climatic and non-climatic parameters on species abundances, we carried out multiple regression analysis on extracted PCs. To inspect the effect of analysed parameters on species diversity, we conducted ordinal multinomial logistic regression on PCs. Analyses were conducted using the R statistical platform (version 3.3.1., R Core Team, 2016).

RESULTS

Species composition

In total, 294 specimens of 20 species were detected in our two oilseed rape field locations. At Crvenka, 13 out of 20 (65%) species were recorded, whereas 14 out of 20 species (70%) were present in Rimski Šančevi.

Calculation of the ecological indices

The most abundant species at both localities was *Eupeodes corollae* (Fabricius, 1794), followed by *Eristalis tenax* (Linnaeus, 1758), and *Episyrphus balteatus* (De Geer, 1776) (Table 1).

Overall species abundance ranged from 1 to 80 individuals per species. In the first year of study (2011), the most abundant species in Crvenka was *E. balteatus* (24 individuals, 35% of all registered species), whereas *E. corollae* was the most numerous in Rimski Šančevi with 16 individuals (94%). In 2012, *E. tenax* was the most abundant species in Crvenka (5 individuals, 24%), and two species were most abundant in Rimski Šančevi (*E. tenax* n=37 (30%) and *E. corollae* n=55 (34%)). In 2013, the most abundant species in Crvenka were *Eristalis arbustorum* (Linnaeus, 1758) and *E. tenax* (each with 3 individuals, 37.5%), and in Rimski Šančevi it was *E. tenax* (21 individuals, 49%).

Table 1. List of species and their abundances recorded in two Brassica napus fields in Vojvodina province, Serbia.

	Sampling localities	
Species	Crvenka	Rimski Šančevi
Cheilosia grossa (Fallen, 1817)	3	0
Cheilosia latifrons (Zetterstedt, 1843)	1	0
Cheilosia sp.	3	0
Dasysyrphus friuliensis (van der Goot, 1960)	1	0
Episyrphus balteatus (De Geer, 1776)	26	17
Eristalinus aeneus (Scopoli, 1763)	2	3
Eristalis arbustorum (Linnaeus, 1758)	7	9
Eristalis pertinax (Scopoli, 1763)	1	0
Eristalis similis (Fallen, 1817)	0	3
Eristalis tenax (Linnaeus, 1758)	28	59
Eupeodes corollae (Fabricius, 1794)	22	80
Eupeodes luniger (Meigen, 1822)	0	1
Helophilus trivittatus (Fabricius,1805)	1	3
Melanostoma mellinum (Linnaeus, 1758)	0	5
Melanostoma scalare (Fabricius, 1794)	0	1
Myathropa florea (Linnaeus, 1758)	0	1
Parhelophilus versicolor (Fabricius, 1787)	1	0
Sphaerophoria scripta (Linnaeus, 1758)	4	7
Syritta pipiens (Linnaeus, 1758)	0	2
Syrphus vitripennis (Meigen, 1822)	0	3
Total	100	194

Slight changes in species composition were recorded throughout the seasons at both localities. The most noticeable difference occurred in the first year of our field study. The most common species (*E. balteatus, E. arbustorum, E. tenax, E. corollae*) were all detected at Crvenka, whereas only two species were recorded (*E. tenax, E. corollae*) at Rimski Šančevi. At Crvenka, species were evenly distributed among the different categories of all three indices (dominance, constancy, and ecological significance index), whereas at Rimski Šančevi only edifying species were detected. In the second year of the study, the gap in species abundance and composition between the two localities was smaller, with Crvenka exhibiting its greatest abundance (10 out of 20 species). Even so, most of the species were in the lower categories of constancy (accidental and accessory species), dominance (subrecedent, recedent, subdominant), and ecological significance (accidental, accessory, accompanying species). *Eristalis arbustorum* and *E. tenax* made a significant contribution to species constancy, while *Cheilosia grossa* (Fallen, 1817) and *Cheilosia* sp. contributed to species dominance. The pattern of species composition at Rimski Šančevi was similar to the previous year. *Sphaerophoria scripta* (Linnaeus, 1758) and *Syritta pipiens* (Linnaeus, 1758) contributed to dominance and ecological significance, along with the three most common species (*E. balteatus, E. tenax* and *E. corollae*). This scenario was reversed for the final year of the study. Crvenka exhibited lower species abundance compared to Rimski Šančevi, it had fewer species in higher categories (e.g. no edifying species), and only one species (*Parhelophilus versicolor* (Fabricius, 1787)) was detected apart from the three most typical species (*E. balteatus, E. tenax, E. corollae*). In the final year, Rimski Šančevi exhibited both its greatest number of species and number of individuals per species. Almost every category of all indices was detected over the course of the three years. The results of our synecological analyses are detailed in Tables 2, 3 and 4.

Shannon-Wiener's index of diversity values ranged from 0.22 to 2.14. The lowest value was recorded in 2011 for Rimski Šančevi, and the highest in 2012 in the same locality. However, overall, Crvenka presented higher values of the Shannon-Wiener index than Rimski Šančevi (Table 5).

Effects of climatic and non-climatic parameters on species assemblage structure

In order to identify factors that influence species composition and abundance, we conducted PCAs. The first PCA generated two PC axes, and the second one generated three PC axes, all with eigenvalues >1 (Table 6). None of the extracted PCs were related to abundance at the significance level of $p<0.05$ ($p=0.4305$, $r=0.0552$) based on multiple linear regressions.

Both PC axes of the first PCA showed a slight correlation with species diversity (PC1: Wald statistic=5.8616, df=1, p=0.01547; PC2: Wald statistic=9.8790, df=1, p=0.00167). The first PC axis was negatively correlated with monthly average temperature and insolation, and positively correlated with monthly relative humidity, wind velocity, cloud cover, locality and surrounding crop diversity. The second PC axis was correlated with monthly average rainfall, season, and year of observation (Table 6, Fig. 2).

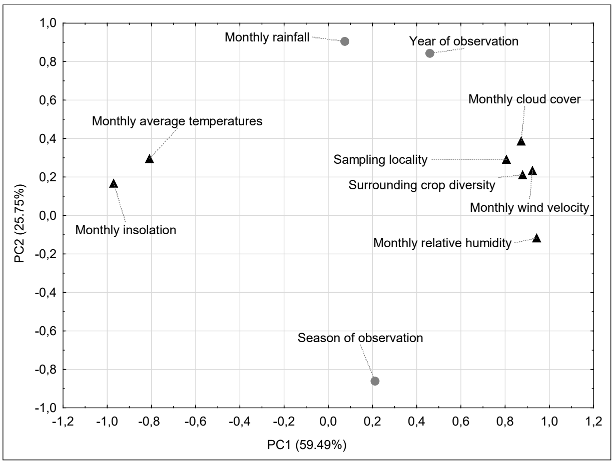

Fig. 2. Projection of analysed variables onto the PC1 and PC2 ordinations. ▲ represents variables significantly correlated with PC1; ● represents variables significantly correlated with PC2.

Table 2. Values of ecological indices for the hoverfly community in Crvenka and Rimski Šančevi in 2011.

	Constancy		Dominance		Significance	
Species	**%**	**Category**	**%**	**Category**	**%**	**Category**
Crvenka, 2011						
Cheilosia latifrons (Zetterstedt, 1843)	50	C3	0.95	D1	0.48	W2
Episyrphus balteatus (De Geer, 1776)	100	C4	24.65	D5	24.65	W5
Eristalis arbustorum (Linnaeus, 1758)	100	C4	3.89	D3	3.89	W3
Eristalis pertinax (Scopoli, 1763)	50	C3	0.95	D1	0.48	W2
Eristalis tenax (Linnaeus, 1758)	100	C4	22.03	D5	18.26	W5
Eupeodes corolla (Fabricius, 1794)	100	C4	38.85	D5	38.6	W5
Helophilus trivittatus (Fabricius,1805)	50	C3	0.95	D1	0.48	W2
Sphaerophoria scripta (Linnaeus, 1758)	100	C4	7.74	D4	7.74	W4
Rimski Šančevi**, 2011**						
Eristalis tenax (Linnaeus, 1758)	50	C3	10	D4	5	W5
Eupeodes corolla (Fabricius, 1794)	100	C4	95	D5	95	W5

Table 3. Values of ecological indices for the hoverfly community in Crvenka and Rimski Šančevi in 2012.

	Constancy		Dominance		Significance	
Species	**%**	**Category**	**%**	**Category**	**%**	**Category**
Crvenka, 2012						
Cheilosia grossa (Fallen, 1817)	16.6	C1	4.63	D3	0.77	W2
Cheilosia sp	16.6	C1	4.63	D3	0.77	W2
Dasysyrphus friuliensis (van der Goot, 1960)	16.6	C1	1.52	D2	1.53	W3
Episyrphus balteatus (De Geer, 1776)	33.34	C2	7.07	D4	2.36	W3
Eristalinus aeneus (Scopoli, 1763)	16.6	C1	3.03	D3	0.5	W2
Eristalis arbustorum (Linnaeus, 1758)	33.34	C2	4.85	D3	1.62	W3
Eristalis tenax (Linnaeus, 1758)	33.34	C2	18.19	D5	6.3	W4
Eupeodes corollae (Fabricius, 1794)	16.67	C1	5.56	D4	0.93	W2
Eupeodes luniger (Meigen, 1822)	16.67	C1	16.67	D5	2.78	W3
Myathropa florea (Linnaeus, 1758)	16.67	C1	16.67	D5	2.78	W3
Rimski Šančevi, 2012						
Episyrphus balteatus (De Geer, 1776)	50	C3	10.34	D5	5.15	W4
Eristalinus aeneus (Scopoli, 1763)	16.67	C1	0.48	D1	0.08	W1
Eristalis arbustorum (Linnaeus, 1758)	33.34	C2	0.86	D1	0.27	W2
Eristalis similis (Fallen, 1817)	33.34	C2	1.15	D2	0.21	W2
Eristalis tenax (Linnaeus, 1758)	33.34	C2	9.37	D4	9.37	W4
Eupeodes corollae (Fabricius, 1794)	33.34	C2	32.13	D5	10.72	W5
Helophilus trivittatus (Fabricius,1805)	16.67	C1	0.95	D1	0.16	W2
Melanostoma mellinum (Linnaeus, 1758)	16.67	C1	0.6	D1	0.09	W1
Melanostoma scalare (Fabricius, 1794)	16.67	C1	0.2	D1	0.03	W1
Sphaerophoria scripta (Linnaeus, 1758)	83.34	C4	0.98	D1	0.51	W2
Syritta pipiens (Linnaeus, 1758)	33.34	C2	8.33	D4	8.86	W3
Syrphus vitripennis (Meigen, 1822)	33.34	C2	0.86	D1	0.29	W2

Table 4. Values of ecological indices for the hoverfly community in Crvenka and Rimski Šančevi in 2013.

	Constancy		Dominance		Significance	
Species	**%**	**Category**	**%**	**Category**	**%**	**Category**
Crvenka, 2013						
Eristalis arbustorum (Linnaeus, 1758)	20	C1	20	D5	4	W3
Eristalis tenax (Linnaeus, 1758)	20	C1	15	D5	3	W3
Eupeodes corollae (Fabricius, 1794)	20	C1	20	D5	4	W3
Parhelophilus versicolor (Fabricius, 1787)	20	C1	5	D3	1	W2
Rimski Šančevi**, 2013**						
Episyrphus balteatus (De Geer, 1776)	40	C2	8.71	D4	3.47	W3
Eristalinus aeneus (Scopoli, 1763)	20	C1	1.21	D3	0.24	W2
Eristalis arbustorum (Linnaeus, 1758)	20	C1	3.64	D3	0.73	W2
Eristalis tenax (Linnaeus, 1758)	60	C3	35.3	D5	21.18	W5
Eupeodes corollae (Fabricius, 1794)	40	C2	12.43	D5	2.5	W3
Helophilus trivittatus (Fabricius,1805)	20	C1	0.61	D1	0.12	W2
Melanostoma mellinum (Linnaeus, 1758)	20	C1	1.21	D3	0.24	W2
Sphaerophoria scripta (Linnaeus, 1758)	40	C2	3.11	D3	1.24	W3

Table 5. Values of Shannon-Wiener's index of diversity in two *Brassica napus* fields from Vojvodina, Serbia.

	Shannon-Wiener's index	
Year of observation	Crvenka	Rimski Šančevi
2011	1.51	0.22
2012	2.14	1.98
2013	1.25	1.68

Table 6. Principal component analysis of 10 climatic and non-climatic variables associated with hoverfly species diversity and abundance in oilseed rape fields from Vojvodina, Serbia. Significant factor loadings are in bold.

	PC1	PC2	PC3	PC1	PC2
Variables	Species abundance			Species diversity	
Monthly average temperatures	-0.18	**0.87**	0.17	**-0.80**	0.29
Monthly relative humidity	0.05	-0.19	**-0.97**	**0.94**	-0.11
Monthly insolation	0.14	-0.27	**0.94**	**-0.96**	0.16
Monthly cloud cover	**0.99**	0.14	0.00	**0.87**	0.38
Monthly rainfall	**0.99**	0.04	-0.02	0.07	**0.90**
Monthly wind velocity	0.41	0.89	0.20	**0.92**	0.23
Sampling locality	0.09	0.90	-0.31	**0.80**	0.29
Year of observation	**0.91**	0.33	0.12	0.45	**0.84**
Season of observation	-0.73	0.16	-0.65	0.21	**-0.86**
Surrounding crop diversity	0.34	**0.84**	-0.28	**0.87**	0.21
Eigenvalue	4.44	3.14	1.91	5.94	2.57
Total variance %	44.40	31.37	19.14	59.49	25.75
Cumulative variance %	44.40	75.77	94.91	59.49	85.25

The influence of variables related with PC1 and PC2 on species diversity is illustrated in Fig. 3. Overall, species diversity increases with increasing temperature, relative humidity and surrounding crop diversity. The left part of the PC1 ordination represents lower surrounding crop diversity (i.e. Crvenka: maize and sugar beet), whereas the right part represents species occurring at the sampling locality with higher crop diversity (Rimski Šančevi: maize, sunflower, sugar beet, wheat, soybean, vegetables, field pea and alfalfa).

DISCUSSION

The most abundant species at both localities over all three years of the study were *E. corollae, E. tenax* and *E. balteatus*. This is not surprising, considering that all of these species are anthropophilic and almost ubiquitous (Speight, 2017). Additionally, these species occur over a wide temperature range (with a tolerance to lower temperatures), and are not conditioned by the diversity of surrounding crops (Fig. 2). Similar findings were noted in a recent study of oilseed rape pollinators in Ireland (Stanley, Gunning, & Stout, 2013). In that study, alongside bumblebees (*Bombus,* Latreille, 1802) and honeybees (*Apis mellifera* Linnaeus, 1761), *Eristalis* Latreille, 1804 hoverflies were one of the most important pollinators of winter crops of oilseed rape based on the amount of pollen they carried, visitation rates and their abundance. Moreover, *E. tenax* is recognised as an efficient pollinator of various cultivated plants (vegetables, fruits, crops), including oilseed rape (Solomon & Kendall, 1970; Kendall et al, 1971; Nye & Anderson, 1974; Jarlan et al*,* 1997; Schittenhelm, Giadis, & Rao, 1997; Jauker et al*,* 2012). This species visits a wide range of flowers, and it can be active even in extremely cold conditions (Speight, 2017). Additionally, it is an anthropophilic species, often found in different types of farmland due to saprophagous larvae (Rotheray & Gilbert, 2011).

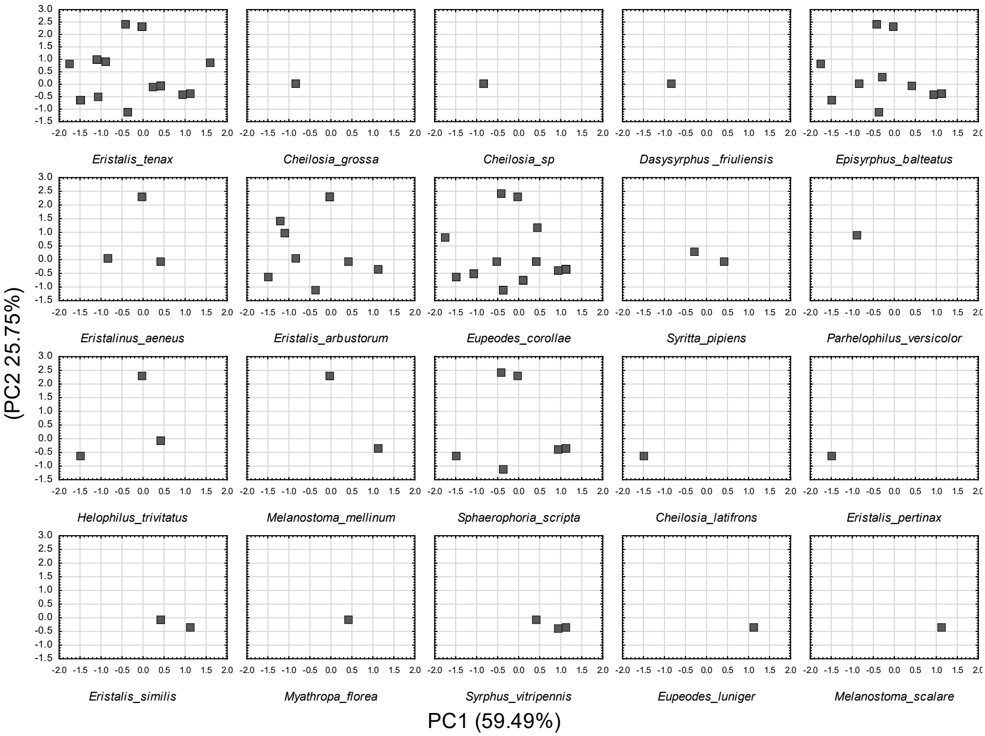

Fig. 3. Scatter plot of factor loadings for the two PC axes, showing the positions of the investigated hoverfly species in the environmental space.

Suitable microhabitats for these larvae are present throughout Vojvodina, so it is not surprising that *E. tenax* is present in the studied area.

It is somewhat expected that two of the most abundant species in our study localities were *E. corollae* and *E. balteatus* since they are predatory hoverflies commonly associated with agricultural habitats (Bergen, Soudhof, & Poehling, 1998; MacLeod, 1999; Sutherland, Sullivan, & Poppy, 2001; Jauker, Diekötter, Schwarzbach, & Wolters, 2009). Larvae of these species can be very useful as biocontrol agents as they feed on aphids, but as adults they are also pollinators for some crops (Hickman & Wratten, 1996). In addition, Jauker et al (2009) recorded that flowers of oilseed rape visited by *E. balteatus* produced significantly more seeds per pod. These authors proposed that apart from pollen transfer, *E. balteatus* enhanced plant self-pollination due to its characteristic behaviour on the flowers.

Our synecological analysis indicated that only a few species (*E. balteatus, E. tenax* and *E. corollae*) make a major contribution to constituting the hoverfly communities on oilseed rape crops. These species, along with *E. arbustorum* and *S. scripta*, may be characterized as the dominant hoverfly visitors of *B. napus*.

It is possible that relatively small number of species recorded is due to use of pan traps as the sampling method. This method has its limitations, since hoverflies are good fliers and do not fall into traps that easily. On the other hand, using pan traps allows simultaneous sampling of multiple locations, coverage of large number of sites, and laboratory identification of specimens (Westphal et al, 2008)

The importance of less abundant hoverfly species should not be underestimated. Gibson, Nelson, Hopkins, Hamlett, & Memmott (2006) found that even though *Platycheirus albimanus* was the least abundant species on their surveyed plots, it carried the highest percentage of pollen. In the same study, they concluded that *S. scripta* was not the most abundant species, but had the highest pollen fidelity. Some species like *Eristalinus aeneus* (Scopoli, 1763) have been found to be better pollinators of *B. napus* than *E. balteatus* and *E. corollae* due to their larger size and their foraging preference for nectar and pollen (Ali, Saeed, Sajjad, & Whittington, 2011). Another such example is *Melanostoma mellinum* (Linnaeus, 1758) that has been found foraging on flowers of *Rosa carolina* L. before sunrise, so it could contribute to pollination during parts of the day when most other pollinators are inactive (Morse, 1981). In our case, only few specimens of these two species were found, but this could be due to methodological limitations of pan trap, or relatively small sample size. Despite certain environmental constraints (solar radiation, temperature, cloud cover, etc.), hoverflies are known to forage under conditions when bees and butterflies are not active (Levesque & Burger, 1982). Thus, even non-abundant hoverfly species should be taken into account when creating agricultural policies and regulations, especially since it is known that abundance of hoverflies (and pollinators in general) is positively correlated with floral abundance and abundance of flowering plant species (Kleijn & van Langevelde, 2006; Meyer, Jauker, & Steffan-Dewenter, 2009; Sajjad et al, 2010). However, in modern agroecosystems, hoverflies face considerable challenges because agricultural intensification negatively affects the heterogeneity and quantity of hoverfly resources at various spatial scales (Benton, Vickery, & Wilson, 2003). In this era of increasing agricultural production, ecologically important habitats are being progressively eroded. Even if the increased area under crops could benefit certain species adapted to this type of habitat, in general it influences negatively the diversity of hoverflies and other pollinators. Therefore, it is of great importance to enhance overall plant species richness through crop rotation and, more importantly, by enlarging field margins and preserving patches of natural habitat within fields. Such areas have been shown to act as important population sources from which pollinators can disperse and thereby contribute to higher densities and species richness of pollinators in adjacent agricultural areas (Duelli & Obrist, 2003; Öckinger & Smith, 2007).

We did not find a statistically significant correlation between climatic parameters and overall abundance of hoverfly species, perhaps due to a lack of variation in the climatic parameters we measured, or relatively small sample size. However, it is possible that these parameters still affected some species or certain stages of their development (e.g. low temperatures at the beginning of the flight period, excessive rainfall at the peak flight period, not enough sunlight, etc.). Also, many factors other than climate can affect species diversity and seasonal patterns, such as food abundance and predation (Wolda, 1988; Abrahamczyk, Kluge, Gareca, Reichle, & Kessler, 2011). Despite the lack of a correlation for overall abundance, our PCA analysis showed that increased surrounding crop diversity contributed to higher numbers of individuals of *E. tenax*, *E. balteatus*, *E. corollae* and *S. scripta* (Fig. 2). Furthermore, the PCA indicated that variation in abundance is also related with temperature range for these four species (Fig. 2).

Focusing on species richness, it is clear that relative humidity and insolation (variables very strongly correlated with PC1) have a major influence on species composition. These variables, together with monthly average temperature, had the greatest impact on species diversity, describing 59.5% of total environmental variation (PC1). Species that can tolerate lower temperatures (up to approximately 10° C) are *Dasysyrphus friuliensis* Goot, 1960, *C. grossa*, *E. tenax, E. arbustorum, Eristalis similis* (Fallen, 1817)*, E. balteatus, E. corollae, Eupeodes luniger* (Meigen, 1822)*, S. scripta, Syrphus vitripennis* (Meigen, 1822) and *Melanostoma scalare* (Fabricius, 1794). Species only occurring at temperatures above 20° C are *Cheilosia latifrons* (Zetterstedt, 1843) and *Eristalis pertinax* (Scopoli, 1763).

Our results also highlight the importance of surrounding crop heterogeneity for species diversity. Some species such as *S. pipiens*, *S. vitripennis*, *M. mellinum*, *M. scalare*, *Myathropa florea* (Linnaeus, 1758), *E. similis* and *E. luniger* were recorded only at Rimski Šančevi (Table 1, Fig. 2). There, unlike in Crvenka, surrounding crops were changed annually, amounting to eight different crops over the three-year study period (maize, sunflower, sugar beet, wheat, soybean, vegetables, field pea and alfalfa).

The relatively recent discovery that Diptera can be a very important component of temperate pollinator communities (Inouye, Larson, Ssymank, & Kevan, 2015), especially at high altitudes, indicates the potential for further investigation. Even though honeybees are considered one of the most efficient pollinators, their presence can sometimes depend on the proximity of hives since their populations are often managed. Thus, their richness and diversity can be low or they can be completely absent from some fields. In such cases, the Syrphidae, solitary bees and other pollinators can be very important. It is crucial that the importance of other pollinator groups is recognized so that they can be taken into consideration when certain agricultural regulations and policies are made. We assert that the significance of Diptera as pollinators should engender the same concern about their conservation that has been raised for pollinators in general (Kearns & Inouye, 1997; Kearns, Inouye, & Waser, 1998; Kearns, 2001) and for pollinators of crops in particular (Allen-Wardell et al, 1998).

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REFERENCES

Abrahamczyk, S., Kluge, J., Gareca, Y., Reichle, S. & Kessler, M. (2011). The influence of climatic seasonality on the diversity of different tropical pollinator groups. *PLoS ONE*, 6, e27115

Ali, M., Saeed, S., Sajjad, A. & Whittington, A. (2011). In search of the best pollinators for canola (*Brassica napus* L.) production in Pakistan. *Applied Entomology and Zoology*, 46, 353-361.

Allen-Wardell, G., Bernhardt, P., Bitter, R., Burquez, A., Buchmann, S., Cane, J., Cox, P.A., Dalton, V., Feinsinger, P., Ingram, M., Inouye, D., Jones, C.E., Kennedy, K., Kevan, P., Koopowitz, H., Medellin, R., Medellin-Morales, S., Nabhan, G.P., Pavlik, B., Tepedino, V., Torchio, P. & Walzer, S. (1998). The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. *Conservation Biology*, 12, 8-17.

Association for the Promotion of Production and Exports of Grains and Oilseeds, (2017, May 5). Retrived from http://www.zitasrbije.rs/tekst.php?grupaA=13.

Bartsch, H., Binkiewicz, E., Rådén, A. & Nasibov, E. (2009). *Nationalnyckeln till Sveriges flora och Fauna. Tvåvingar: Blomflugor: Syrphidae. Diptera: Syrphidae: Syrphinae. & Diptera: Syrphidae: Eristalinae & Microdontinae*. Artdatabanken, SLU, Uppsala.

Bacandritsos, N., Granato, A., Budge, G., Papanastasiou, I., Roinioti, E., Caldon, M., Falcaro, C., Gallina, A. & Mutinelli, F. (2010). Sudden deaths and colony population decline in Greek honey bee colonies. *Journal of Invertebrate Pathology*, 105, 335-340.

Benton, T.G., Vickery, J.A. & Wilson, J.D. (2003). Farmland biodiversity: is habitat heterogeneity the key?. *Trends in Ecology & Evolution*, 18, 182-188.

Bergen, H., Soudhof, K. & Poehling, N.M. (1998). Prey finding of larvae and adult females of *Episyrphus balteatus*. *Entomologia Experimentalis et Applicata*, 87, 245-254.

Biesmeijer, J.C., Roberts, S.P.M., Reemer, M., Ohlemuller, M., Edwards, M., Peeters T., Schaffers, A.P., Potts, S.G., Kleukers, R., Thomas, C.D., Settele J., Kunin W.E. (2006). Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science,* 313, 351-354.

Buchmann, S.L. & Nabhan, G.P. (1997). *The forgotten pollinators*. Island Press, Washington, DC, California.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., O'Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. & van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature,* 387, 253-260.

Duelli, P. & Obrist, M.K. (2003). Biodiversity indicators: the choice of values and measures. *Agriculture, Ecosystems & Environment*, 98, 87-98.

Gibson, R.H., Nelson, I.L., Hopkins, G.W., Hamlett, B.J. & Memmott, J. (2006). Pollinator webs, plant communities and the conservation of rare plants: arable weeds as a case study. *Journal of Applied Ecology*, 43, 246-257.

Genersch, E., Von Der Ohe, W., Kaatz, H., Schroeder, A., Otten, C., Büchler, R., Berg, S., Ritter, W., Mühlen, W., Gisder, S. & Meixner, M. (2010). The German bee monitoring project: a long term study to understand periodically high winter losses of honey bee colonies. *Apidologie*, 41, 332-352.

Gligorov, V., Kovacevic, M., Josifidis, K., Paunovic, B., Bjelic, P., Kovacevic, A., Djurdjev, B., Novkovic, B., Ivanic, V., Vuckovic, S., Popovic, D., Lepotic Kovacevic, B., Medovic, V., Knezevic, I., Sokic, M. & Milojevic, T. (2010). *Competitiveness of Economy of Vojvodina*. Center for Strategic Economic Studies "Vojvodina-CESS" Government of AP Vojvodina, Novi Sad.

Grall, J. & Coïc, N. (2005). *Summary of quality assessment of coastal benthos methods*, Rebent, University of Bretagne, France.

Hadžić, V., Nešić, Lj. & Sekulić, P. (2005). Land and its protection in modern agriculture. Proceedings from *XXXVIII Agronomists counselling*, Institute of Field and Vegetable crops (in Serbian), Novi Sad, 5-15.

Hickman, J.M. & Wratten, S.D. (1996). Use of *Phelia tanacetifolia* strips to enhance biological control of aphids by overfly larvae in cereal fields. *Journal of Economic Entomology*, 89, 832-840.

Inouye, D.W., Larson, B.M., Ssymank, A. & Kevan, P.G. (2015). Flies and flowers III: ecology of foraging and pollination. *Journal of Pollination Ecology*, 16, 115-133.

Jarlan, A., de Oliveira, D. & Gingras, J. (1997). Pollination by *Eristalis tenax* (Diptera: Syrphidae) and seed set of greenhouse sweet pepper. *Journal of Economic Entomology,* 90, 1646-1649.

Jauker, F., Bondarenko, B., Becker, H.C. & Steffan-Dewenter, I. (2012). Pollination efficiency of wild bees and hoverflies provided to oilseed rape. *Agricultural and Forest Entomology*, 14, 81-87.

Jauker, F., Diekötter, T., Schwarzbach, F. & Wolters, V. (2009). Pollinator dispersal in an agricultural matrix: opposing responses of wild bees and hoverflies to landscape structure and distance from main habitat. *Landscape Ecology*, 24, 547-555.

Kearns, C.A. (2001). North American dipteran pollinators: assessing their value and conservation status. *Conservation Ecology*, 5, 1-13.

Kearns, C.A. & Inouye, D.W. (1997). Pollinators, flowering plants, and conservation biology. *Bioscience*, 47, 297-307.

Kearns, C.A., Inouye, D.W. & Waser, N.M. (1998). Endangered mutualisms: the conservation of plant-pollinator interactions. *Annual Review of Ecology and Systematics*, 29, 83-112.

Kendall, D.A., Wilson, D., Guttridge, C.G. & Anderson, H.M. (1971). Testing *Eristalis* as a pollinator for covered crops. *Long Ashton Research Station Report,* 1971, 120-121.

Kleijn, D. & van Langevelde, F. (2006). Interacting effects of landscape context and habitat quality on flower visiting insects in agricultural landscapes. *Basic and Applied Ecology*, 7, 201-214.

Kunin, W.E. (1993). Sex and the single mustard: Population density and pollinator behavior effects on seed-set. *Ecology,* 74, 2145-2160.

Larson, B.M.H., Kevan, P.G. & Inouye D.W. (2001). Flies and flowers: taxonomic diversity of anthophiles and pollinators. *The Canadian Entomologist,* 133, 439-465.

Leong, J.M. & Thorp, R.W. (1999). Colour-coded sampling: the pan trap colour preferences of oligolectic and nonoligolectic bees associated with a vernal pool plant. *Ecological Entomology*, 24, 329-335.

Levesque, C.M. & Burger, J.F. (1982). Insects (Diptera, Hymenoptera) associated with *Minuartia groenlandica* (Caryophyllaceae) on Mount Washington, New Hampshire, USA, and their possible role as pollinators. *Arctic and Alpine Research*, 2, 117-124.

MacLeod, A. (1999). Attraction and retention of *Episyrphus balteatus* DeGeer (Diptera: Syrphidae) at an arable field margin with rich and poor floral resources. *Agriculture, Ecosystems & Environment*, 73, 237-244.

Meyer, B., Jauker, F. & Steffan-Dewenter, I. (2009). Contrasting resource-dependent responses of hoverfly richness and density to landscape structure. *Basic and Applied Ecology*, 10, 178-186.

Milošević, D., Ignjatov, M., Nikolić, Z., Stanković, I., Bulajić, A., Marjanović-Jeromela, A. & Krstić, B. (2016). The presence of Turnip yellows virus in oilseed rape (*Brassica napus* L.) in Serbia. *Pesticidi i fitomedicina*, 31, 37-44.

Morse, D.H. (1981). Interactions between syrphid flies and bumblebees on flowers. *Ecology*, 62, 81-88.

Nye, W.P. & Anderson, J.L. (1974). Insect pollinators frequenting strawberry blossoms and the effect of honeybees on yield and fruit quality. *Journal of the American Society for Horticultural Science*, 99, 40-44.

Öckinger, E. & Smith, H.G. (2007). Semi-natural grasslands as population sources for pollinating insects in agricultural landscapes. *Journal of Applied Ecology*, 44, 50-59.

Pineda, A. & Marcos-García, M.Á. (2008). Use of selected flowering plants in greenhouses to enhance aphidophagous hoverfly populations (Diptera: Syrphidae). *Annales de la Société Entomologique de France*, 4, 487-492.

Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O. & Kunin, W.E. (2010). Global pollinator declines: trends, impacts and drivers. *Trends in ecology & evolution*, 25, 345-353.

Potts, S.G., Roberts, S.P., Dean, R., Marris, G., Brown, M.A., Jones, R., Neumann, P. & Settele, J. (2010). Declines of managed honey bees and beekeepers in Europe. *Journal of Apicultural Research*, 49, 15-22.

R Development Core Team, (2016). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna. Available at http://www.R-project.com

Rathke, G., Behrens, T. & Diepenbrock, W. (2006). Effects of nitrogen source and rate on productivity and quality of winter oilseed rape (*Brassica napus* L.) grown in different crop rotations. *Field Crops Research*, 94, 103-113.

Rotheray, G.E. & Gilbert, F. (2011). *The natural history of hoverflies*. Forrest text.

Hydrometeorological Service of the Republic of Serbia, 2011 (2016, September 25). *Meteorološki godišnjak 1. Klimatološki podaci 2011.* Retrieved from http://www.hidmet.gov.rs/podaci/meteo_godisnjaci

Hydrometeorological Service of the Republic of Serbia, 2012 (2016, September 25). *Meteorološki godišnjak 1. Klimatološki podaci 2012.* Retrieved from http://www.hidmet.gov.rs/podaci/meteo_godisnjaci

Hydrometeorological Service of the Republic of Serbia, 2013 (2016, September 25). *Meteorološki godišnjak 1. Klimatološki podaci 2013.* Retrieved from http://www.hidmet.gov.rs/podaci/meteo_godisnjaci

Roubik, D.W. (1995). *Pollination of cultivated plants in the tropics*. Food and Agricultural Organization of the United Nations, Rome, Italy.

Sajjad, A. & Saeed, S. (2010). Floral host plant range of syrphid flies (Syrphidae: Diptera) under natural conditions in southern Punjab, Pakistan. *Pakistan Journal of Botany*, 42, 1187-1200.

Schittenhelm, S., Giadis, T., & Rao, V.R. (1997). Efficiency of various insects in germplasm regeneration of carrot, onion and turnip rape accessions. *Plant Breeding*, 116, 369-375.

Solomon, M.E. & Kendall, D.A. (1970). Pollination by the syrphid fly, *Eristalis tenax*. *Long Ashton Research Station Report*, 1970, 101-102.

Speight, M.C.D. (2017). Species accounts of European Syrphidae, 2017. *Syrph the Net, the database of European Syrphidae (Diptera)*, vol. 97, 294, Syrph the Net publications, Dublin.

Stanley, D.A., Gunning, D. & Stout, J.C. (2013). Pollinators and pollination of oilseed rape crops (*Brassica napus* L.) in Ireland: ecological and economic incentives for pollinator conservation. *Journal of Insect Conservation*, 17, 1181-1189.

StatSoft Inc. STATISTICA (data analysis software system), version 13.2, 2017, Retrieved from: www.statsoft.com

Sutherland, J.P., Sullivan, M.S. & Poppy, G.M. (2001). Oviposition behaviour and host colony size discrimination in *Episyrphus balteatus* (Diptera: Syrphidae). *Bulletin of Entomological Research*, 91, 411-417.

Thompson, F.C. (2013). *Family Syrphidae.* In Thompson, F. C., Pape, T. (Eds.). *Systema Dipterorum*, version 1.5. Retrieved from http://www.diptera.org

van der Velde, M., Bouraoui, F. & Aloe, A. (2009). Pan-European regional-scale modelling of water and N efficiencies of rapeseed cultivation for biodiesel production. *Global Change Biology*, 15, 24-37.

van Veen, M.P. (2004). *Hoverflies of Northwest Europe: identification keys to the Syrphidae*. KNNV Publishing, Utrecht, The Netherlands.

Vujić, A., Šimić, S. & Radenković, S. (2002). New data on hoverflies diversity (Insecta: Diptera: Syrphidae) on the Fruška Gora mountain (Serbia). *Proceedings for Natural Sciences, Matica Srpska, Novi Sad*, 103, 91-106.

Westphal, C., Bommarco, R., Carré, G., Lamborn, E., Morison, N., Petanidou, T., Potts, S.G., Roberts, S.P., Szentgyörgyi, H., Tscheulin, T. & Vaissière, B.E. (2008). Measuring bee diversity in different European habitats and biogeographical regions. *Ecological monographs*, 78, 653-671.

Westrich, P. (1989). *Die Wildbienen Baden-Württembergs*. Ulmer, Stuttgart, Germany.

Williams, I.H. (1994). The dependences of crop production within the European Union on pollination by honey bees. *Agricultural Zoology Reviews (United Kingdom)*, 6, 229-257.

Wolda, H. (1988). Insect seasonality: why?. *Annual Review of Ecology and Systematics*, 19, 1-18.

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