THE GROUND BEETLE (COLEOPTERA: CARABIDAE) COMMUNITY IN AN INTENSIVELY MANAGED AGRICULTURAL LANDSCAPE

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Abstract. The effects of intensive agricultural management practices and environmental changes on biodiversity can be monitored by using the carabid beetles as biological indicators of agroecosystems quality. This study aimed to investigate the ground beetle species composition, abundance, dominance, diversity, zoogeographical types and distribution groups in an intensively managed agricultural field. Epigeic carabid fauna was collected weekly using pitfall traps on an arable crop field in Podravina, Croatia. Altogether, 1429 individuals belonging to 26 species and 15 genera were collected. The most abundant and eudominant were *Poecilus cupreus* (Linnaeus, 1758), followed by *Brachinus psophia* Audinet-Serville, 1821 and *Pterostichus melas melas* (Creutzer, 1799). Two species were dominant, two subdominant, four recedent and 15 subrecedent. The diversity of fauna was moderately high: Simpson diversity index 0.7875, Shannon-Wiener index 1.9654 and Pielou's evenness 0.6032. Zoogeographical analysis showed equal dominance of Euroasian and Palearctic species. Most (73%) of species belonged to E and 27% to A relict class. The majority of species were spring breeders (14 species), 8 species were autumn breeders and one species breeds in both seasons. In intensively managed agricultural landscape, ground beetle diversity was moderately high, because most of the species were eurytopic, i.e. capable of inhabiting strongly anthropogenically influenced landscapes.
Keywords: *Carabidae species composition, ecological factors, zoogeographical types, intensive crop production, agro-technical measures*

Introduction

Ground beetles are species rich and abundant in agricultural land all over the world (Lövei and Sunderland, 1996). As one of the most abundant and diverse groups overwintering within cultivated fields (Holland and Reynolds, 2003), they are often used in cultivation experiments. Carabids have also been successfully used for different kinds of indicator studies, serving as biological indicators of agroecosystems quality (Cole et al., 2002; O´Rourke et al., 2008). Most of these studies focus on beetles' response to agricultural management practices or changing environmental conditions (Rainio and Niemelä, 2003). According to Baranova et al. (2013), in terms of environmental quality, arable land represents an anthropogenically influenced, unstable and devastated biotope with low contribution to farmland diversity. Due to ground beetles' sensitive reaction to anthropogenic changes in habitat quality (Avgın and Luff, 2010), they have a bioindicative value for cultivation impacts, as well as for environmental change (Thiele, 1977; Maelfait, 1990).

Environmental change, through many abiotic and biotic factors, can cause different kinds of effects on the indicator species, including changes in species

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number and distribution (Blake et al., 1996; Rainio and Niemelä, 2003). Abiotic factors most often include temperature and soil moisture (Lövei and Sunderland, 1996; Holland, 2002). Other authors reported on many additional factors: landscape heterogeneity (Chapman, 2014), field size (Kromp, 1999), the presence of non-cropped habitat (Pollard, 1968; Sotherton, 1985) and land use diversity (Östman et al., 2001). Ground beetle abundance can be influenced by the crop-dependent timing of cultivation measures (Hence et al., 1990). According to Stassart and Grégoire-Wibo (1983), the depth of tillage is one of the major factors affecting the carabid fauna. Fertilization regimes (e.g. manure, mineral fertilizers) could also have a positive effect on ground beetle population (Pietraszko and De Clercq, 1982; Hence and Grégoire-Wibo, 1987) or a negative one (Kromp, 1990). Vician et al. (2015) considered the content of organic matter and pH as the most significant factors influencing ground beetle diversity in agroecosystems, while others stated soil particle size distribution can be a decisive factor in habitat selection (Thiele, 1977; Meissner, 1984).

Crop type can affect ground beetles through modification of microclimatic factors (i.e. temperature and humidity) and through disturbance factors (i.e. harvest and tillage schedules) (Thiele, 1977; Witmer et al., 2003; O´Rourke et al., 2008). The ground beetles population in the agricultural landscape can be also influenced by chemical pest control (Basedow, 1987; Asteraki et al., 1992; Jeschke et al., 2011; Szczepaniec et al., 2011; Varvara et al., 2012; Douglas et al., 2014).

Several studies in Croatia reported about epigeic ground beetles' assemblage, distribution and abundance in different vegetation types, including forests (Šerić Jelaska, 2005; Brigić et al., 2014a), wetlands (Brigić et al., 2014b), meadows (Durbešić, 1987; Durbešić et al., 2006) and parks (Durbešić, 1982; Marković, 2009). However, not many detailed studies about ground beetles on agricultural fields with intensive land cultivation have been done. Studies were performed on leguminous fields (Kovačević and Balarin, 1960; Balarin, 1974) and in wheat (Sekulić et al., 1973; Sekulić, 1977). The most comprehensive ground beetle faunal study on several different crop types was done in Podravina region more than 30 years ago (Štrbac, 1983), in which 31 species were identified. Since then, only few researchers investigated ground beetle assemblage in agricultural landscape, and these included research on sugar beet (Kos et al., 2013), maize (Kos et al., 2006; Bažok et al., 2007; Kos et al., 2011) and barley (Kos et al., 2010). The latest study on endogeic ground beetle communities in arable field in Podravina area revealed eight species (Drmić et al., 2016). Juran et al. (2013) investigated activity of the adult ground beetles in three differently managed fields in central Croatia and found that the endogaeic activity was highest in „organic" system, followed by the „conventional" and „integrated" system. Büchs et al. (2013) found 72 species on differently managed fields in a neighboring country. The authors, however, did not mention the species composition.

Different indices measure different aspects of the partition of abundance between species. Species evenness usually has been defined as the ratio of observed diversity to maximum diversity, the latter being said to occur when the species in a collection are equally abundant (Margalef, 1958; Patten, 1962; Pielou, 1966). Simpson's index, for example, is sensitive to the abundance only of the more plentiful species in a sample, and can therefore be regarded as a measure of "dominance concentration" (Whittaker, 1965). Used Shannon index is an

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information statistic index, which means it assumes all species are represented in a sample and that they are randomly sampled. This index estimates the affinity of different populations belonging to a community and, through the species composition, the similarity of the habitats (Popescu and Zamfirescu, 2004).

In modern intensively managed production in Croatia, there is still little knowledge on beneficial fauna importance (Bažok et al., 2015; Virić Gašparić et al., 2017). In order to preserve biodiversity in intensively managed arable land as much as possible, it is important to monitor the bioindicator species such as ground beetles, since they can indicate the anthropogenically influenced field quality. Detailed knowledge on their community in a specific agricultural landscape can give us a preview on agroecosystem stability. Therefore, this study aimed to investigate the ground beetle species composition, abundance, dominance and diversity, as well as zoogeographical types and distribution groups in an intensively managed agricultural field, with its specific agro-ecological factors and agro-technical measures.

Materials and methods

Location

Ground beetles were collected during the arable crop growing season in 2015 in Lukač (Virovitica–Podravina County, Croatia), on winter crop field with an intensive arable management and specific climatic and edaphic characteristics (field size 34.76 ha, coordinates: 45° 50′ 24″ N, 17° 24′ 0″ E). According to Köppen classification, this part of continental Croatia belongs to *Cfwbx* climatic type characterized with continental climate of cold winters and hot summers (Penzar and Penzar, 2000). The soils in the research area are gleyic luvisols (IUSS Working Group WRB 2015). These are hydromorphic soils, characterized by periodic or continuous wetting of part or whole of the profile, with stagnating precipitation or with additional surface or underground water that is not saline or alkaline. These soils contain a great amount of fine sand and coarse silt (sandy loams texture) (Bogunović et al., 1996) and often require conventional tillage.

The field was chosen to represent common cultivation practices as well as the agro-technical measures in this area. Considering the soil type and soil characteristics, the tillage was adapted to the given conditions and performed as follows: a) in autumn: ploughing on a depth of 20-25 cm was followed by the furrow closure for moisture conservation in spring; b) in spring: chisel ploughing and tillage with the rotary harrow; c) in summer: after harvest disk harrowing and again chisel ploughing. A description of the regional physical and chemical soil properties of investigated area as well as agrotechnical measures applied on the experimental field are given in *Table 1*. Performed pedological procedure consisted out of taking the soil sample from the depth of a plow layer (30 cm). Five sub-samples waging 300–400 g were taken and than pooled and homogenized for analysis. Analysis was performed by the pedology laboratory of the Department of Soil Science, Faculty of Agriculture, University of Zagreb and included sediment grain size and chemical properties analyses. Soil texture was determined by sieving following standard methods (ISO 11277 2004) (Kozina et al., 2015).

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Table 1. *Physical and chemical soil properties of arable field where research was conducted*

Location	Soil type	Soil pH	Humus (%)	Soil properties (mm)	Fertilization	Bare soil (mth)*	Insecticide treatment
Lukač (Virovitica -Podravina County)	gleyic luvisol	KCl 5.58 H2O 6.65	3.2	Coarse sand 2.35 Fine sand 11.83 Coarse silt 38.42 Fine silt 31.65 Clay 15.75	74 kg N 60 kg P 90 kg K	2	Thiacloprid

*number of months while field was not covered after harvesting till soil preparing for crops grown in folowing vegetation season

Climatic factors

Climate data (i.e., mean weekly air temperature, mean weekly soil temperature and the total amount of rainfall per week) were obtained from the Croatian Meteorological and Hydrological Service and presented for ground beetle collecting period from May to September 2015 (19^{th} to 38^{th} week of the year).

Ground beetle trapping

Epigeic covered pitfall traps were used to collect adult ground beetles. Polythene pots (Ø=12 cm, h=18 cm) were incorporated 18 cm into the soil and covered with PVC roofs (Ø=16 cm) approximately 4 cm above ground level. Each trap was half filled with salted water (20% solution) for captures conservation. Four pitfall traps were placed into the center of the field at 50 m apart and 100 m away from the field edges. Trapping was performed from the 19^{th} to the 38^{th} week of the year, from May to September 2015. Traps were inspected once a week and all ground beetles were collected and counted. The identification of the collected ground beetles to species level was based on the work of Auber (1965), Bechyne (1974), Harde and Severa (1984) and Freude et al. (2006).

Ground beetle composition analysis

The ground beetle trapping results using pitfall traps for the selected interval (from 19^{th} to 38^{th} week of the year) are presented as a mean number of individuals caught per field per week. Results of the ground beetle population dynamics are presented as the total number of ground beetles caught per week as a function of the average weekly air temperatures (°C), total weekly precipitation (mm) and average weekly temperature of soil (°C) at a depth of 10 cm.

The dominance values of carabids presented in percentage shares of a particular species in the community were calculated according to Tischler (1949) as follows: eudominant (10-100%), dominant (5-10%), subdominant (2-5%), recedent (1-2%) and subrecedent (<1%). To calculate the diversity of the carabid assemblages, Simpson (λ) and Shannon-Wiener indices (H') were used. Shannon-Wiener indices is an entropy, giving the uncertainty in the outcome of a sampling process key (Jost, 2006). Both

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Shannon and Simpson diversities increase as richness increases, for a given pattern of evenness, and increase as evenness increases, for a given richness, but they do not always rank communities in the same order (Colwell, 2009). Evenness was estimated using Pielou's evenness. Analyses were carried out using the MATLAB program (The MathWorks Inc., 2015). Zoogeographical analysis adding new species records and contributing an understanding of the composition (Majka et al., 2007), was made according to Vigna Taglianti et al. (1999) and the database Fauna Europaea (Vigna Taglianti, 2013). The distribution/occurrence groups (relict classes E, A and R) were defined according to Hůrka et al. (1996).

Results and discussion

This study aimed at observation and description of a ground beetle fauna during one vegetation season in intensive arable crop production. During the sampling period, a total of 1429 individuals were collected using epigeic traps at Podravina region. Ground beetles collected belong to 26 species and 15 genera (*Table 2*) which in comparison with previous studies in arable agroecosystems can be classified as moderately high (Kos et al., 2006; Bažok et al., 2007; Kos et al., 2010, 2011; Drmić et al., 2016; Virić Gašparć et al., 2017). Despite the large number of species which may occur in agroecosystems, a relatively small number have been identified as being characteristic of arable areas and these are often the most abundant (Thiele, 1977; Holland and Luff, 2000).

The composition of recorded species in arable crops corresponds with results of similar investigations in Croatia (Kos et al., 2006; Bažok et al., 2007; Igrc Barčić et al., 2008; Kos et al., 2010; 2011; Drmić et al., 2016) and abroad (Bukejs and Balalaikins, 2008; Woodcock et al., 2010; Baranová et al., 2013). The most abundant species in the total catch was *Poecilus (Poecilus) cupreus cupreus* (Linneaus, 1758) (37.65%) followed by *Brachinus (Brachinus) psophia* Audinet-Serville, 1821 (21.06%) and *Pterostichus (Feronidius) melas melas* (Creutzer, 1799) (10.29%) (*Table 2*). The most abundant species accounted almost 70% of the total catch and belonged to the group of eudominant species. *Anchomenus (Anchomenus) dorsalis* (Pontoppidan, 1763) and *Harpalus (Pseudoophonus) rufipes* (DeGeer, 1774) were classified as dominant, *Amara (Amara) similata* (Gyllenhal, 1810) and *Pterostichus (Morphosoma) melanarius melanarius* (Illiger, 1798) as subdominant while others were recedent (4 species) or subrecedent (15 species). The species, which dominated the carabid assemblage in arable habitat (with the total collections), were *P. cupreus* (538), *B. psophia* (301), *P. melas* (147), *H. rufipes* (128) and *A. dorsalis* (97) (*Table 2*).

Species *P. cupreus* is considered as one of the most common species inhabitating winter crops (Alford, 2008), so these results strongly support this research. In Croatia, Štrbac (1983) also specified it among the three most dominant on arable land.

Drmić et al. (2016) investigated endogaeic ground beetle fauna in the same area in Croatia and detected *B. psophia* and *A. dorsalis* as the most abundant ones, therefore we may assume that these species are a typical arable ground beetle representatives in investigated region.

Species *P. melas* is also common in Croatia and was detected as dominant in agricultural land near the Nature park Lonjsko polje (Brigić et al., 2003).

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Table 2. *The composition, abundance, zoogeographical and geographical analysis of ground beetles collected in Lukač, 2015*

Species name	**N†**	**DV‡**	**Zoogeographical categories and faunal types§**	**Geographical distribution groups|**	**Reproduction period¶**
Calosoma (Campalita) auropunctatum auropunctatum Herbst, 1784	1	0.07	E-CAS	A	no data found
Brachinus (Brachinus) crepitans Linné, 1758	27	1.89	B-CAS	E	Sp
Brachinus (Brachinus) psophia Audinet-Serville 1821	301	21.06	E-CAS	E	no data found
Brachinus (Brachynidius) explodens Duftschmid 1812	3	0.21	E-CA-M	E	Sp
Clivina fossor fossor Linné, 1758	13	0.91	E-AS	E	Sp
Asaphidion curtum curtum Heyden 1870	3	0.21	OLA	E	Sp
Trechus (Trechus) quadristriatus Schrank, 1781	4	0.28	E-CA-M	E	A
Anisodactylus (Pseudanisodactylus) signatus Panzer 1796	1	0.07	E-AS	E	Sp
Harpalus (Harpalus) affinis Schrank, 1781	1	0.07	E-AS	E	Sp
Harpalus (Harpalus) dimidiatus P. Rossi, 1790	1	0.07	E-PAS	A	A
Harpalus (Harpalus) distinguendus distinguendus Duftschmid, 1812	2	0.14	PAL	E	Sp
Harpalus (Pseudoophonus) rufipes DeGeer, 1774	128	8.96	PAL	E	A
Stenolophus (Stenolophus) teutonus Schrank, 1781	16	1.12	E-MED	E	Sp
Agonum (Amara) viridicupreum viridicupreum Goeze, 1777	1	0.07	E-PA-M	E	Sp
Anchomenus (Anchomenus) dorsalis Pontoppidan, 1763	97	6.79	PAL	E	Sp
Abax (Abacopercus) carinatus carinatus Dejean, 1828	4	0.28	E-PAS	A	no data found
Abax (Abax) parallelepipedus parallelepipedus Piller & Mitterpacher, 1783	1	0.07	EUR	A	A
Poecilus (Poecilus) cupreus cupreus Linné, 1758	538	37.65	E-AS	E	Sp
Pterostichus (Feronidius) melas melas Creutzer, 1799	147	10.29	E-PAS	A	A
Pterostichus (Morphosoma) melanarius melanarius Illiger, 1798	54	3.78	E-SI	A	A
Pterostichus (Platysma) niger niger Schaller, 1783	1	0.07	E-AS	A	A
Calathus (Calathus) fuscipes fuscipes Goeze, 1777	19	1.33	PAL	E	A/Sp
Calathus (Neocalathus) ambiguus ambiguus Paykull, 1790	1	0.07	E-AS	E	A
Amara (Amara) aenea Degeer, 1774	3	0.21	OLA	E	Sp
Amara (Amara) ovata Fabricius, 1792	28	1.96	PAL	E	Sp
Amara (Amara) similata Gyllenhal, 1810	34	2.38	E-AS	E	Sp

† N-number of individuals; ‡ DV-dominance index; § I. Northern Holarctic and Euro-Siberian faunal type: OLA - Holarctic; PAL - Palearctic; E-SI - Eurosiberian; II. European faunal type: EUR - European; E-PAS - European-Neareastern; III. Euroasiatic faunal type: E-AS - Euroasiatic steppe complex; E-CAS - European and Central Asian; B-CAS - Balkan and Central Asian; IV. Mediterranean (s. lato) faunal type: E-CA-M - European-Centralasian-Mediterranean; E-PA-M - European-Neareastern-Mediterranean; E-MED - Eastmediterranean (Vigna Taglianti et al. 1999, the database Fauna Europaea (Vigna Taglianti, 2013)); | Relict classes: E-eurytopic species, A-adoptable species; ¶ A-autumn, Sp-spring.

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Kromp (1999) listed species *H. rufipes*, followed by *P. cupreus* and *P. melanarius* as the most abundant from agricultural fields of Eastern European countries, which is generally in accordance with our results. Similar investigations from Croatia (Bažok et al., 2007; Igrc Barčić et al., 2008; Kos et al., 2011) also stated species *H. rufipes* and *P. melanarius* in the group of the most abundant species in corn fields. Although they were not the most abundant species in our results, they were among species which generally dominated with the total scores.

This typically structured ground beetle community of arable land consists of a small number of dominant species represented with a large number of individuals and a large number of less commonly occurring species (subdominant, recedent and subrecedent) represented with a low number of specimens (Baranová et al., 2013).

The diversity of fauna was moderately high: Simpson (1-λ') diversity index was 0.7875, Shannon-Wiener index (H') was 1.9654 and Pielou’s evenness was 0.6032. Analysis of faunal types (zoogeographical analyses) showed the dominance of Euroasian (23.08%) and Palearctic (23.08%) species which corresponds with climatic and geographic characteristics of the investigated area (*Table 2*).

With reference to relict classes, 73% of determined ground beetles belonged to E relict class which consists of eurytopic species without special demands on habitat type and quality, and inhabiting strongly anthropogenically influenced landscapes (Hůrka et al., 1996). Species which belonged to A relict class were represented with 27% and this group included more adoptable species, which are found in more or less natural habitats (forests, meadows, pastures, standing and flowing water) (Hůrka et al., 1996). Neither one species was classified to relict class R, which was expected, because R class includes species with narrow ecological amplitude, which are rare and endangered, occurring naturally in undisturbed ecosystems which was not the case in our study (Hůrka et al., 1996). These results correspond to the results of Porhajašová et al. (2004) and Baranová et al. (2013) who reported that increasing human disturbances changes the composition to favor eurytopic species while reducing the number of specialized species with narrow ecological valences.

Abundance and diversity as well as the ratio of spring to autumn breeders varied between winter sown crops (cereals and oilseed rape) and spring sown root crops (potatoes, sugar beet, maize, carrots) (Kabacik-Wasylik, 1975 cit. Holland and Luff, 2000). Winter crops usually have higher abundance, diversity and more spring breeders with summer larvae (e.g. *P. cupreus*, *A. dorsalis*) which was confirmed with our results as well. These preferences are not, however, always apparent and even total numbers may vary (Holland and Luff, 2000). The majority of collected species were spring breeders (14 species), 8 species were autumn breeders and one species (*Calathus fuscipes fuscipes* (Goeze, 1777)) breeds in both seasons (*Table 2*). The domination of spring breeders could be a consequence of the cultivation measures. The depth of tillage is one of the major factors affecting field carabid communities, with superficial ploughing enabling a higher number of species and favoring spring breeders (Kromp, 1999 cit. Stassart and Grégoire-Wibo, 1983).

Species composition and the number of ground beetles in different agrocenosis differ and depend on edaphic factors (Bukejs and Balalaikins, 2008). Ground beetle species contribute significantly to the insect diversity in farmland because many species are adapted to agriculture and generally occur at high densities (Booij, 1994). According to Thiele (1977) and Kromp (1999) cultivated land is comprised of widely distributed, eurytopic ground beetle species, many of which have high tolerance to disturbances and

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chemical pollution. This means that cultivated land contains a typical ground beetle fauna, despite the regular implementation of cultivation measures (Kromp, 1999). For example, Thiele (1977) listed 26 species found at investigated arable habitats stretching from England over Central Europe.

In our survey the first population maximum was observed from week 19th to 21st which was also the beginning of sample collection period. The second population maximum was recorded from week 32nd to 36th (*Figure 1*). Presented results of ground beetle population dynamics show that population increase follows air and soil temperature decrease (*Figure 1*). In the whole investigation period the number of ground beetle decrease is followed by precipitation increase. Recording to Croatian Meteorological and Hydrological Service the Virovitica-Podravina County is described as mid worm area with intensive periods of rainfall especially in summer period.

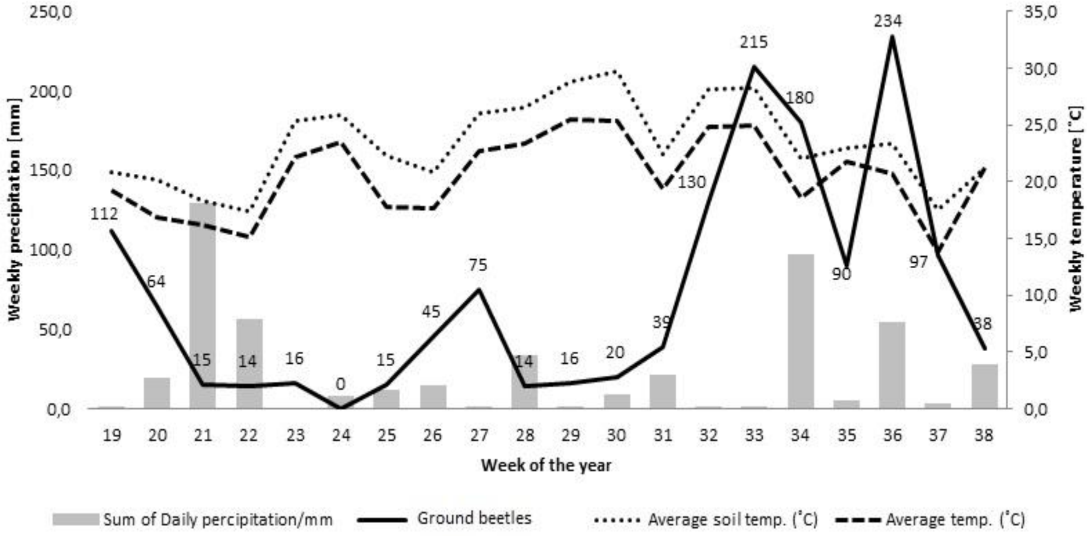

Figure 1. *Ground beetles weekly dynamics with prevailing climatic conditions*

According to edaphic factors prevailing at investigation area ground beetles inhabited slightly acidic soil with a great amount of fine silt and a small proportion of clay (*Table 1*). The intensity of ploughing was the main agro-technical specificity at studied locality. The field in Podravina has been ploughed often and on great depth during whole vegetation season. Ploughing is known to significantly influence physico-chemical and biological soil properties and affects the abundance of invertebrates (Vician et al., 2015). Generally, reduced soil disturbance, increased surface residues and greater weed diversity had positive impact on invertebrates (Kromp, 1999). According to previous studies, higher ground beetle trapping rates were recorded on fields with reduced tillage or no tillage at all compared with conventionally tilled ones (House and All, 1981; Blumberg and Crossley, 1983; House and Stinner, 1983; Ferguson and McPherson, 1985; House and Parmalee, 1985; Stinner et al., 1988; Tonhasca, 1993). Conventional tillage, such as conducted on the field in Podravina, could have an impact on established ground beetles abundance.

The soil factors are greatly influenced by weather conditions and ploughing but also could be affected by crops growing at the area. Previous studies have shown that microclimatic factors, such as temperature and humidity, and disturbance factors such

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as harvest and tillage schedules crops affect ground beetles communities (Thiele, 1977; Holland, 2002). Although no ground beetle species appears to be strictly bound to a certain crop, early agro-ecological studies in Europe reported a general difference between ground beetle abundance distributions in winter versus spring crops (Heydemann, 1955). O´Rourke et al. (2008) stated that thick stand winter crops provide important refuges for ground beetles in comparison with spring crops. The overwintering crop sown at the field in our survey may confirm the importance of crop habitat for supporting ground beetle populations by providing less extreme microhabitat in spring and creates positive conditions for ground beetle survival and the dominance of spring breeders.

Beside crop specifics, bare soil period can also be a significant factor that affects ground beetle communities. In winter crops, the less extreme microclimate already established in early spring creates favorable conditions for ground beetles (Kromp, 1999). Locality in our study had a very short period of bare soil (2 months period without plant cover; *Table 1*). No negative effect was observed in ground beetle populations regarding the extreme soil surface microclimate. The effect of intensively managed crop on ground beetles abundance which could be detected in this research support the results of numerous other studies (Tonhasca, 1993; Zhang et al., 1998; Honek and Jarosik, 2000; Ward and Ward, 2001; Witmer et al., 2003; O´Rourke et al., 2008).

As well, the fertilization in Podravina is generally intensive while insecticide treatments were common and in compliance with IPM. While previous studies had concluded that insecticides have negative influence on the ground beetle populations (Asteraki et al., 1992, 1995), more detailed investigation are needed for the full conclusion. Kromp (1999) shown that high amount of nitrogen used in fertilization process decrease ground beetle abundance. The levels of nitrogen applied in Podravina are under permitted levels (EU Directive 2009/128/EC, EUR-Lex, 2009) causing minimal negative influence on ground beetles. Only mineral fertilization has been used in Podravina so possible positive effect of organic manure recorded by Pietraszko and De Clercq (1982) and Hence and Grégoire-Wibo (1987) on ground beetle communities cannot be discussed.

Conclusions

The bioindicator species such as ground beetles have not received much attention by researchers in Croatia, although they can indicate the anthropogenically influenced field quality. In this study we gained detailed knowledge on their community in a specific agricultural landscape in northwest Croatia, Podravina region. In this investigation, a total of 1429 ground beetles were collected using epigeic traps, belonging to 26 species and 15 genera. Ground beetle diversity was moderately high, because most of the species were eurytopic, i.e. capable of inhabiting strongly anthropogenically influenced landscapes. In modern agriculture in European Union, conservation programs aimed to keep beneficial species and biodiversity are promoted as tool for ensuring sustainability. In order to measure the success of such programs, one has to have detailed knowledge on the initial situation. The results of this study significantly contributed to better understanding of initial situation about ground beetle communities in intensive agricultural landscape in northwest Croatia and will be a good entry point for future conservation programs.

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