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Variations in Carabidae assemblages across the farmland habitats in relation to selected environmental variables including soil properties

Zmeny spoločenstiev bystruškovitých rôznych typov habitatov poľnohospodárskej krajiny v závislosti od vybraných environmentálnych faktorov vrátane pôdnych vlastností

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Abstract

The variations in ground beetles (Coleoptera: Carabidae) assemblages across the three types of farmland habitats, arable land, meadows and woody vegetation were studied in relation to vegetation cover structure, intensity of agrotechnical interventions and selected soil properties. Material was pitfall trapped in 2010 and 2011 on twelve sites of the agricultural landscape in the Prešov town and its near vicinity, Eastern Slovakia. A total of 14,763 ground beetle individuals were entrapped. Material collection resulted into 92 Carabidae species, with the following six species dominating: *Poecilus cupreus, Pterostichus melanarius, Pseudoophonus rufipes, Brachinus crepitans*, *Anchomenus dorsalis* and *Poecilus versicolor*. Studied habitats differed significantly in the number of entrapped individuals, activity abundance as well as representation of the carabids according to their habitat preferences and ability to fly. However, no significant distinction was observed in the diversity, evenness neither dominance. The most significant environmental variables affecting Carabidae assemblages species variability were soil moisture and herb layer 0-20 cm. Another best variables selected by the forward selection were intensity of agrotechnical interventions, humus content and shrub vegetation. The other from selected soil properties seem to have just secondary meaning for the adult carabids. Environmental variables have the strongest effect on the habitat specialists, whereas ground beetles without special requirements to the habitat quality seem to be affected by the studied environmental variables just little.

Keywords: arable land, ground beetles, meadows, non-crop habitats, soil moisture

Abstrakt

Zmeny v spoločenstvách bystruškovitých (Coleoptera: Carabidae) troch typov habitatov poľnohospodárskej krajiny, t.j. ornej pôdy, trvalo trávnych porastov a mimolesnej krovinovej vegetácie boli sledované v závislosti od štruktúry vegetačnej pokrývky, intenzity agrotechnických zásahov a vybraných pôdnych vlastností. Materiál bol zbieraný metódou formalínových zemných pascí v rokoch 2010 a 2011 v rámci 12-tich stanovíšť poľnohospodárskej krajiny v urbánnej zóne mesta Prešov a jeho blízkeho okolia na východnom Slovensku. V rámci uvedeného zberu bolo odchytených celkovo 14 763 jedincov a determinovaných 92 druhov bystruškovitých. Dominantnými druhmi boli: *Poecilus cupreus, Pterostichus melanarius, Pseudoophonus rufipes, Brachinus crepitans*, *Anchomenus dorsalis* and *Poecilus versicolor*. Spoločenstvá sledovaných biotopov sa signifikantne líšili v počte odchytených jedincov, epigeickej aktivite ako aj zastúpení bystrušiek vo vzťahu k ich habitatovým preferenciám a letovým schopnostiam. Výskum však nepotvrdil signifikantné rozdiely v diverzite, ekvitabilite ani dominancii. Z nami sledovaných environmentálnych premenných kompozíciu spoločenstva bystruškovitých najvýznamnejšie ovplyvňuje pôdna vlhkosť a vegetačný kryt s výškou 0-20 cm. Ďalšími významnými premennými, ktoré vplývajú na kompozíciu spoločenstva sú intenzita agrotechnických zásahov, obsah pôdneho humusu a krovinová vegetácia. Ostatné zo sledovaných pôdnych vlastností majú na dospelé jedince bystrušiek len sekudárny vplyv. Rovnako, environmentálne premenné najvýraznejšie ovplyvňujú habitatových špecialistov, zatiaľ čo druhy bystrušiek bez vyhranených nárokov na podmienky prostredia sú ovplyvnené uvedenými faktormi len málo.

Kľúčové slová: bystruškovité, mimoprodukčné habitaty, orná pôda, pôdna vlhkosť, trvalo trávne porasty

Introduction

As it was confirmed by several authors, ground beetles as a typical representatives of soil fauna are heavily connected with soil properties. The occurrence and distribution of Carabidae could be especially influenced by pH, sodium chloride and calcium content, numbers of species is perceptive to soil moisture changes (Šustek, 1990; Bezděk, 2001; Rainio and Niemela, 2003; Lovei, 2008; Avgın and Luff, 2010; Koivula, 2011). Soil moisture, soil structure and temperature, physical and chemical properties, quality and quantity of the organic matter and its availability during the season are strongly affected through the agrotechnical actions. Agronomic technologies, such a soil tillage, cultivation or fertilisation have a significant, although not always positive effect on soil properties. They can stimulate humus degradation, the leaching of nutrients and accumulation of weed seeds, pathogens or pests in soil. Thus the agrotechnical actions indirectly affect the abundance, diversity as well as activity of the Carabidae beetles (Baguette and Hance, 1997; Holland and Reynolds, 2003; Lazzerini et al., 2007; Ivask et al., 2008; Veselý and Šarapatka, 2008; Smith et al., 2009; Sadej et al., 2012).

Ground beetles and their occurrence across the farmland habitats and in connection to different factors have been studied by several authors: Lovei (1984), Bukejs and

Balalaikins (2008), Varvara and Apostol (2008), Bukejs (2009), Haschek et al. (2012) monitored Carabidae coenoses in the fields with different crops, Clark (1999), Döring and Kromp (2003), Porhajašová et al. (2004, 2008 a, b), Raworth et al. (2004), Diekötter et al. (2010) evaluated ground beetles assemblages across the arable land under the different farming systems and management characteristics. Occurrence of the ground beetles across the arable land in connection to selected soil properties were evaluated by Holopainen et al. (1996) or Sadej et al. (2012). Grass fields Carabidae assemblages were studied by Grandchamp et al. (2005), Humbert et al. (2009), Tuff et al. (2011), communities of non crop habitats as hedgerows or windbreaks by Fournier et al. (1998), Varchola and Dunn (2001), de la Peña et al. (2003), Olechowicz (2007), Šustek (2008).

Materials and methods

The study was carried out in 2010 and 2011 in the Prešov town and its near vicinity, Eastern Slovakia. Three types of habitats most frequently occurring in farmland were studied: arable land (al)-SOal-2010, TEal-2011, RUal-2011, SEal-2011 including fields with different crops, sunflower (*Helianthus annuus*, site SOal-2010), maize (*Zea mais*, site TEal-2011), oil-seed rape (*Brassica napus*, site RUal-2011) and wheat (*Triticum aestivum*, site SEal-2011); meadows (m)-SOm-2011, TEm-2011, RUm-2011, KAm-2011 i.e. grass fields grazed by sheep (site RUm-2011) or harvested twice a year (sites SOm-2010, TEm-2011, KAm-2011) and woody vegetation (w)-SOw-2010, TEw-2011, RUw-2011, SEw-2011 characterised as the small-scale group of scrubs dominated by *Prunus spinosa* L. and *Rosa canina* L. (sites SOw-2010, RUw-2011), small-area tree vegetation with dominance of *Salix* sp. (site SEw-2011) and mixture of *Sambucus nigra* L., *Crataegus monogyna* Jacq. and *Salix* sp. (site TEw-2011).

Carabidae beetles were trapped using three formaline pitfall traps in each site, placed in a line with 25 meters spacing, exposed from May till July, mid of September till end of October and picked up in two to four week period. Material from 36 traps in total here is mentioned. Members of *Carabidae* family were identified up to species level using key of Hůrka (1996) and the comparative material of The Šariš Museum in Bardejov. Carabidae species were also classified into the groups based on their habitat preferences and ability to fly, the body size was evaluated too (Hůrka, 1996). At each study site: vegetation cover structure estimated in % of (1) herb layer (0-20 cm above ground), (2) herb layer (20-50 cm above ground), (3) shrub layer (50-400 cm above ground) and (4) tree layer (>400 cm above ground) during the peak of vegetation season were determined (Brändle et al., 2000) and intensity of agrotechnical interventions evaluated as the number of harvesting or ploughing realised during the researched period. Following soil properties were evaluated too: a) soil reaction (pH, determined in 0.01 M $CaCl_2$ using inoLab pH 720 WTW), b) soil moisture, W (%) using gravimetric method, c) bulk density, ρ_d ($t*m^{-3}$), d) bulk soil moisture, bulk W (bulk %), e) water retention capacity, WRC (bulk %) and f) soil porosity, Po (%) determined in 100 cm^3 Kopecky´s physical cylinders, g) organic carbon, Cox (%) converted into humus (%) (Fiala, 1999) and h) available phosphorus, P ($mg*kg^{-1}$), i) potassium, K ($mg*kg^{-1}$) and j) magnesium, Mg ($mg*kg^{-1}$) contents evaluated with Mehlich III. Soil samples were taken twice within the growing season from depth 5-15 cm, in spring and early autumn. For the statistical data processing, average of both values was used.

The number of entrapped *Carabidae* individuals was standardised per number of effectively used traps and per number of days of exposition. Data was evaluated for the particular sites, then as the average sum for the studied types of habitats, i.e. arable land, meadows and woody vegetation. Except number of entrapped individuals and activity abundance, taxonomic richness as a number of identified species and the relative abundance (r.a.), i.e. representation of particular species and groups within the community were determined too. Assemblages diversity and evenness were assessed through Shannon (H) and Equitability (J) (J=H*log S) indices, dominance through Dominance (D) index. One-way ANOVA was used to analyse differences between the habitat type in the number of individuals, activity abundance, taxonomic richness, diversity, evenness and dominance, species representation, relative abundance of ground beetles' habitat preferences and flying ability groups as well as environmental variables monitored (Hammer et al., 2001). The data was log-transformed before the statistical analysis. Average values were evaluated using univariate statistics (Hammer et al., 2001). Species similarity was assessed through Jaccard´s similarity index. The proportional similarity of the communities were assessed through Renkonen index of dominance identity (Losos et al., 1984). Mutual differences between assemblages based on the different activity abundance were evaluated through hierarchical cluster analysis of similarity, Ward´s method, determined in PAST 2.17c (Hammer et al., 2001). To assess correlations between the environmental variables, Spearman correlation coefficient determined in STATISTICA 10 by $P<0.01$; 0.05 was used. Forward Selection function was used for selection of statistically significant variables. The species data were transformed prior to the analysis [log(x+1)]. Those variables that did not fit normal distribution were transformed. Ordination was carried out using Canonical Correspondence Analysis (CCA) using CANOCO software, version 4 (Ter Braak and Šmilauer, 1998). Only species with weight and fit range from 5-100% were included into the CCA ordination plot figure.

Results

A total of 14,763 ground beetle individuals belonging to 92 species were evaluated (Table 1).

Six species, *Poecilus cupreus* (28.8%), *Pterostichus melanarius* (18.2%), *Pseudoophonus rufipes* (17.2%), *Brachinus crepitans* (7.96%), *Anchomenus dorsalis* (3.98%) and *Poecilus versicolor* (2.85%) were with the eudominant, dominant or subdominant representation (>2%) across the all habitat types studied, species just changed their range in particular assemblages. Lowest representation of *Poecilus cupreus* (6.7%) was assigned for woody vegetation, highest (40.9%) for arable land. *Pterostichus melanarius* showed the lowest representation across meadows (4.5%), highest across arable land (23.6%). This distinction was assigned as significant ($P<0.05$). Representation of *Pseudoophonus rufipes* varied from 12% across meadows to 26.6% across woody vegetation. *Brachinus crepitans* representation varied between 3.39% across arable land and 20.3% across woody vegetation. *Anchomenus dorsalis* showed lowest representation (2.49%) across woody vegetation, highest (4.8%) across meadows. Representation of *Poecilus versicolor* varied significantly between the studied types of habitats (P<0.05), lowest representation shoved species across arable land (0.04%), highest (23%) across meadows. Although the both species of *Poecilus* genus recorded are characterised as the species of open dry habitats without obscuration, *Poecilus cupreus* dominated arable land, while *P. versicolor* apparently prefers meadows in general. Among other species, *Carabus cancellatus, C. granulatus, C. violaceus, Harpalus affinis* and *Pterostichus niger* were with the representation >1% in general, *Carabus granulatus*, *C. violaceus* and *Pterostichus niger* with the highest representation across the woody vegetation, *C. cancellatus* and *Harpalus affinis* across the arable land. Distinction between arable land and woody vegetation in the representation of *H. affinis* was significant (P<0.05).

Small local concentration of *Abax parallelepipedus*, *Anisodactylus signatus*, *Platyderus rufus*, *Pterostichus anthracinus* and *P. strenuus* was observed across the woody vegetation, *Amara proxima* and *Harpalus latus* across the meadows. Remarkable high activity abundance shoved *Leistus ferrugineus* across the site KAm-2011, *Bembidion tetracolum*, *Brachinus crepitans, Nebria brevicollis*, *Platyderus rufus*, *Pterostichus anthracinus*, *P. niger*, *P. oblongopunctatus* and *P. strenuus* across the site TEw-2011. Among the sampled species, several less common were recorded including *Abax schueppeli rendschmidti*, *Amara montivaga*, *Diachromus germanus, Harpalus caspius roubali*, *Lasiotrechus discus* and *Panagaeus cruxmajor*.

The peak of the ground beetles seasonal activity was assigned across the woody vegetation sites in May, till across the meadows and arable land sites in June.

Table 1a. Survey of ground beetle species across the particular study sites, sum activity abundance for entire researched period

Carabidae species	SOal-2010	TEal-2011	RUal-2011	SEal-2011	SOm-2010	TEm-2011	RUm-2011	KAm-011	SOw-2010	TEw-2011	RUw-2011	SEw-2011
Abax carinatus (Duftschmid, 1812)	0.33		0.33						5			
Abax ovalis (Duftschmid, 1812)							0.33				0.33	
Abax parallelepipedus (Piller et Mitterpacher, 1783)			1.67				1.49		15.3	1	23.7	
Abax parallelus (Duftschmid, 1812)			1.67				0.67		0.66		5.49	
Abax schueppeli rendschmidti (Germar, 1839)			0.66								12.7	
Acupalcus meridianus (Linnaeus, 1761)		0.67										
Agonum gracilipes (Duftschmid, 1812)	0.33					0.33	0.5					
Agonum muelleri (Herbst, 1784)	11.7	1.83	0.33							1		
Amara aenea (De Geer, 1774)			0.66	7.66		10.3						
Amara aulica (Panzer, 1797)	9.67			0.33		0.33	1.33	2.66		3.3		1.32
Amara bifrons (Gyllenhal, 1810)	1											
Amara communis (Panzer, 1797)						5.5	1.66			16		
Amara curta (Dejean, 1828)								0.33				
Amara eurynota (Panzer, 1797)										1		
Amara familiaris (Duftschmid, 1812)						0.33						
Amara montivaga (Sturm, 1825)								0.33				
Amara ovalis (Fabricius, 1792)			5			0.67						
Amara plebeja (Gyllenhal, 1810)			0.67	0.67	0.5	13.5			0.33			

Table 1b. Survey of ground beetle species across the particular study sites, sum activity abundance for entire researched period

Carabidae species	SOal-2010	TEal-2011	RUal-2011	SEal-2011	SOm-2010	TEm-2011	RUm-2011	KAm-011	SOw-2010	TEw-2011	RUw-2011	SEw-2011
Amara proxima (Putzeys, 1866)			0.67		4	26.5	2.33	0.99		1		
Amara similata (Gyllenhal, 1810)	0.33		10.8					0.33				
Anchomenus dorsalis (Pontoppidan, 1763)	9	54.3	63.8	34.7	2	16.3	0.33	15.3	1.66	25.5	7	0.33
Anisodactylus binotatus (Fabricius, 1787)						4.66						0.33
Anisodactylus signatus (Panzer, 1797)	0.33	36.5	0.66			1.33				18.6		
Asaphidion flavipes (Linnaeus, 1761)	1.67									0.7		0.33
Badister bullatus (Schrank, 1798)						0.33		1.33		0.3	0.33	0.67
Badister sodalis (Duftschmid, 1812)									0.33			
Bembidion guttula (Fabricius, 1779)		0.5			2.5	4.5		0.33				
Bembidion lampros (Herbst, 1784)	1.66		0.33	0.67		0.5						
Bembidion properans (Stephens, 1828)	10	0.99	0.33	1	0.5	3.1	3.84			0.3		
Bembidion quadrimaculatum (Linnaeus, 1761)	0.33	36.2		0.33		2.17				1		
Bembidion tetracollum (Say, 1823)										21.6		
Brachinus crepitans (Linnaeus, 1758)	7.33	59.4	31.7	27		50.5	0.33	3.67	0.67	280	0.33	
Calathus fuscipes (Goeze, 1777)	3.33	5.4	2.33	3.67		3.67	0.33	2		11.7		
Calathus melanocephalus (Linnaeus, 1758)	2				5				0.33	3.3	0.33	
Carabus arvensis carpathus (Born, 1902)									1			
Carabus cancellatus (Illiger, 1798)	16.3		37				1.67	1.33	0.33		8.99	0.33

Table 1c. Survey of ground beetle species across the particular study sites, sum activity abundance for entire researched period

Carabidae species	SOal-2010	TEal-2011	RUal-2011	SEal-2011	SOm-2010	TEm-2011	RUm-2011	KAm-011	SOw-2010	TEw-2011	RUw-2011	SEw-2011
Carabus convexus (Linnaeus, 1758)			0.33				0.33				4	
Carabus coriaceus (Linnaeus, 1758)									0.33		1	
Carabus granulatus (Linnaeus, 1758)	19.4	26.1	6.83	15	1.5	10.5			3.66	19.1	2.34	8
Carabus hortensis (Linnaeus, 1758)											5.83	
Carabus scheidleri (Panzer, 1799)	2	1		1.33	2.5				8.67			0.66
Carabus violaceus (Linnaeus, 1758)	0.66	2.1	3.67	1.34		2.66	3.84	2.67	5.66	28.8	2.67	19.7
Clivina fossor (Linnaeus, 1758)	4.99	4.84	0.33			1.33	0.67			1.3		
Cylindera germanica (Linnaeus, 1758)	0.33	1.87	0.83	0.33		1.66		1				
Diachromus germanus (Linnaeus, 1758)						0.5						
Dolichus halensis (Schaller, 1783)		3.33	1.5							1		
Dyschirius globosus (Herbst, 1783)									0.33			
Epaphius secalis (Paykull, 1790)		0.33			6.5						0.67	
Harpalus affinis (Schrank, 1781)	11.7	31	7.16	35.7		15.8		0.66		1	0.33	
Harpalus caspius roubali (Schauberger, 1928)											0.33	
Harpalus distinguendus (Duftschmid, 1812)		1	0.33	0.67		0.67						
Harpalus latus (Linnaeus, 1758)	0.33	0.33	0.33	2.66	3	1.99	1.66	11.7	0.66	4	2.34	1.33
Harpalus luteicornis (Duftschmid, 1812)		0.33	0.33	11.4	0.5	2.49		2.33				1
Harpalus quadripunctatus (Dejean, 1829)								0.33				

Table 1d. Survey of ground beetle species across the particular study sites, sum activity abundance for entire researched period

Carabidae species	SOal-2010	TEal-2011	RUal-2011	SEal-2011	SOm-2010	TEm-2011	RUm-2011	KAm-011	SOw-2010	TEw-2011	RUw-2011	SEw-2011
Harpalus rubripes (Duftschmid, 1812)	0.33						0.33					
Harpalus tardus (Panzer, 1797)				7.67								0.33
Chlaenius festivus (Panzer, 1796)										0.3		
Chlaenius nitidulus (Schrank, 1781)						0.67				0.3		
Chlaenius tibialis (Dejean, 1826)		2										
Lasiotrechus discus (Fabricius, 1792)										0.3		
Lebia chlorocephala (Hoff., Koch, P. Müll. et Linz,							0.33					
Leistus ferrugineus (Linnaeus, 1758)					0.5		0.66	29.3	0.67	4.3	3.49	3
Leistus piceus (Froelich, 1799)											0.33	
Loricera pilicornis (Fabricius, 1775)										0.3		
Microlestes minulutus (Goeze, 1777)						0.33						
Molops piceus (Panzer, 1793)									1.67	0.3	0.33	
Nebria brevicollis (Fabricius, 1792)	0.33	0.5				0.66	0.33			18.3		
Notiophilus palustris (Duftschmid, 1812)	0.33			0.33	1	1		0.33	0.33	2.4		
Oodes helopiodes (Fabricius, 1792)							0.83					
Ophonus azureus (Fabricius, 1775)				4.34		1.33						0.33
Ophonus nitidulus (Stephens, 1828)									0.33	0.3		
Ophonus rufibarbis (Fabricius, 1792)				0.33	1			0.33	0.33	4.2	0.33	0.33

Table 1e. Survey of ground beetle species across the particular study sites, sum activity abundance for entire researched period

Carabidae species	SOal-2010	TEal-2011	RUal-2011	SEal-2011	SOm-2010	TEm-2011	RUm-2011	KAm-011	SOw-2010	TEw-2011	RUw-2011	SEw-2011
Ophonus rupicola (Sturm, 1818)						1.17	0.33					
Ophonus schaubergerianus (Puel, 1937)	0.33									0.3		
Panagaeus cruxmajor (Linnaeus, 1758)			0.83			1	0.33					0.66
Platyderus rufus (Duftschmid, 1812)			0.33							32.9	0.33	0.33
Platynus assimilis (Paykull, 1790)											0.66	0.33
Poecilus cupreus (Linnaeus, 1758)	284	883	330	16.7	5	52	4.68	0.33	5.67	85.3	1.67	0.33
Poecilus versicolor (Sturm, 1824)	0.67		0.33	0.33	113	16.3	27	5	0.33	1.3	1	
Pseudoophonus rufipes (De Geer, 1774)	33.7	419	35.8	56.3	10	67.5	2.16	3	4.67	357	5.34	1.66
Pterostichus anthracinus (Illiger, 1798)	0.33	11.8	1		0.5	3.32		0.33	0.33	27.7		
Pterostichus diligens (Sturm, 1824)										1		
Pterostichus macer (Marsham, 1802)			0.5			1.67				1		
Pterostichus melanarius (Illiger, 1798)	644	54.7	125	51.7	20.5	5	5	1.33	28.7	106	1.66	13
Pterostichus niger (Schaller, 1793)	4.67	3.67	3.5	2.32	5	1.66	0.33	0.66	13	24	0.99	1
Pterostichus nigrita (Paykull, 1790)			0.5				0.33					
Pterostichus oblongopunctatus (Fabricius, 1787)			0.67		0.5					11.5	1.33	
Pterostichus strenuus (Panzer, 1797)			0.67		3	17	0.33	3		11.5	2.66	
Pterostichus vernalis (Panzer, 1796)	1.33		0.66			3.49	0.33	0.33				
Stomis pumicatus (Panzer, 1796)				4.67	0.5							

Table 1f. Survey of ground beetle species across the particular study sites, sum activity abundance for entire researched period

Carabidae species	SOal-2010	TEal-2011	RUal-2011	SEal-2011	SOm-2010	TEm-2011	RUm-2011	KAm-011	SOw-2010	TEw-2011	RUw-2011	SEw-2011
Synuchus vivalis (Illiger, 1798)		1										
Trechus quadristriatus (Schrank, 1781)		2.33	1.66			0.66						

Table 2. Coenological characteristics and results of One-way ANOVA indicating the significant differences between the studied types of habitats in the number of entrapped individuals and activity abundance

	SOal-2010	TEal-2011	RUal-2011	SEal-2011	average	SOm-2010	TEm-2011	RUm-2011	KAm-2011	average	SOw-2010	TEw-2011	RUw-2011	SEw-2011	average
Taxa	29	34	41	27	32.75	23	44	31	28	31.5	27	43	31	22	30.75
Individuals	3,575	3,614	1,901	867	2,489*/ **	410	1,032	183	274	474.75 **	425	2,022	294	166	726.75 *
Activity abundance	1,085	146	682	289	925.50 **	189	357	64.6	91.3	175.48 **	101	1,132	98.8	55.3	346.78
Shannon (H)	1.51	1.33	1.82	2.49	1.79	1.71	2.9	2.72	2.55	2.47	2.55	2.27	2.98	2.19	2.5
Equitability (J)	0.45	0.37	0.49	0.75	0.52	0.55	0.77	0.79	0.76	0.72	0.77	0.6	0.87	0.71	0.74
Dominance (D)	0.42	0.36	0.29	0.12	0.3	0.38	0.1	0.2	0.16	0.21	0.14	0.18	0.1	0.21	0.16

*P<0.01, **P<0.05.

From the studied types of habitats, the highest number of entrapped individuals, highest activity abundance as well as evaluated species was assigned for the arable land. But, the arable land assemblage equally shoved the lowest diversity, evenness and highest dominance. Lowest number of entrapped individuals and activity abundance were assigned for the meadows, the lowest number of evaluated species was evaluated for the woody vegetation. Habitats of meadows and woody vegetation shoved comparable diversity and evenness.

There were no differences between the studied types of habitats in the taxonomic richness, diversity, evenness neither dominance. However, arable land differed significantly in the number of entrapped individuals in comparing to woody vegetation and meadow, as well as in the activity abundance in comparing to meadows (Table 2), what reflected also in the cluster analysis.

The highest species similarity was observed between the assemblages of arable land and meadows (65%), highest species distinction between the meadows and woody vegetation (43%). Anyway, across each site and habitat type studied, there were the equal species with eudominant, dominant and subdominant representation evaluated. The highest proportional similarity was assigned for the arable land and woody vegetation assemblages.

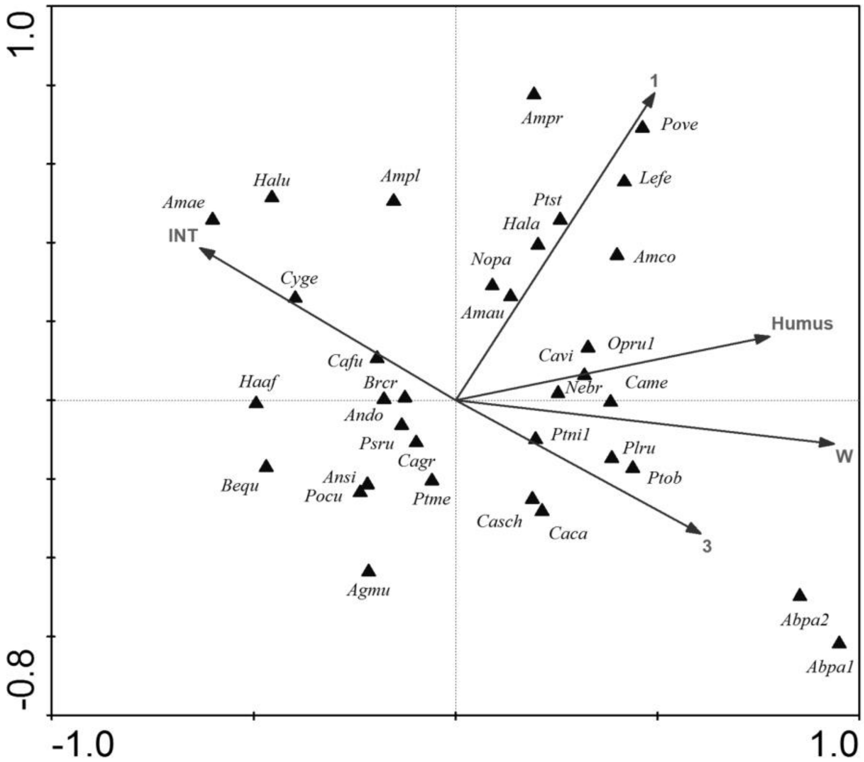
From the farmland habitat studied, arable land was characterised by the huge representation of dry open habitats species (89.82%) and the lowest average representation of open humid habitats species (6.23%), humid habitats species (3.77%) and silvicolous species (0.19%). In opposite, the lowest representation of carabids preferring dry open habitats without shadowing was assigned for the woody vegetation (56.39%). The habitat equally shoved the highest r.a. of species preferring humid or even forest habitats. The representation of dry open habitat species and humid habitat species varied significantly between the arable land and meadows as well as arable land and woody vegetation ($P<0.05$; $P<0.05$; $P=0.01$; $P<0.01$). Following trend was observed too: the site RUw-2011 was characterised be the highest representation of silvicolous species and was in the smallest distance from the nearest forest formation. In opposite, at the site SEw-2011, in the biggest distance from the nearest forest formation, silvicolous species absent at all. However, any correlation was confirmed between these parameters. Concerning ability to fly, the lowest average representation of flying species (51.71%) was assigned for the woody vegetation, highest (80.63%) for assemblage of meadows. In opposite, assemblage of woody vegetation shoved the highest average representation of non-flying species (48.3%), lowest representation (19.37%) was assigned for the meadows. No distinction was observed between the habitats in the representation of flying nor non-flying species. Average ground beetles body size increase in sequence m-al-w.

Table 3. Environmental variables used in the CCA analysis and the results of One-way ANOVA indicating significant differences between the study types of habitats in the porosity, organic carbon, humus and potassium contents

	SOal-2010	TEal-2011	RUal-2011	SEal-2011	average	SOm-2010	TEm-2011	RUm-2011	Kam-2011	average	SOw-2010	TEw-2011	RUw-2011	SEw-2011	average
1 (%)	0	0	0	0	0	40	60	40	40	45	10	10	10	10	10
2 (%)	100	100	100	100	100	60	40	60	60	55	10	10	10	10	10
3 (%)	0	0	0	0	0	0	0	0	0	0	60	60	60	20	50
4 (%)	0	0	0	0	0	0	0	0	0	0	20	20	20	60	30
INT	2	2	2	2	2	2	4	1	2	2.25	0	0	0	0	0
pH ($CaCl_2$)	4.9	6.3	6.3	6.1	5.9	4.6	6.2	6.8	6.3	5.9	3.9	6.6	6.9	7	6.1
W (%)	16.1	11.61	15.24	8.3	12.81	17.55	12.32	30.67	14.7	18.65	20.65	15.99	23.93	16.5	19.27
ρ_d (t*m^{-3})	1	1.28	1.27	1.13	1.7	0.92	1.04	0.98	1.09	1	1.4	1.26	1.04	1.04	1.09
bulk W	16.08	14.44	19.1	9.31	14.73	16.27	13.11	29.61	15.7	18.67	21.85	20.08	24.57	17.64	21.03
WRC	37.88	29.94	28.66	29.53	31.5	37.46	29.84	37.51	31.66	34.12	38.09	37.57	34.17	29.5	34.72
Po (%)	32.22	51.93	52.29	53.3	54.93*	65.21	52.67	63.21	58.95	60.01	60.73	60.94	60.94	60.76	60.84*
Cox (%)	1.28	1.65	1.21	1.21	1.34**	6.89	1.77	2.54	1.71	3.23	2.99	1.85	2.23	3	2.52**
Humus (%)	2.2	2.85	2.9	2.09	2.31**/°	4	3.6	4.39	2.5	3.6	5.15	3.19	3.84	5.17	4.34**/°
P [mg*kg^{-1}]	60	23	59	130	68	<20	88	23	55	41.5	<20	49	<20	64	28.25
K [mg*kg^{-1}]	194	135	131	159	155°°	378	295	331	247	313°°	115	255	257	430	264
Mg [mg*kg-	264	500	212	219	299	381	479	528	349	434	164	298	267	405	284

*P=0.05; **P=0.005; °P=0.01; °°P=0.001. Abbreviations and notes: 1-herb layer (0-20 cm above ground), 2-herb layer (20-50 cm above ground), 3-shrub layer (50-400 cm above ground), 4-tree layer (>400 cm above ground), INT-intensity of agrotechnical interventions, W–soil moisture, ρ_d-bulk density, bulk W-bulk soil moisture, WRC-water retention capacity, Po-porosity, Cox-organic carbon, P-phosphorus content, K-pottasium content, Mg-magnesium content.

Following correlations were observed between the environmental variables (Table 3): soil moisture positively correlated with the bulk soil moisture, soil porosity, organic carbon and humus contents, negatively with the bulk density (P<0.01). Equally, negative correlation of the soil moisture, bulk soil moisture and humus content with the intensity of agrotechnical interventions (P<0.05) was observed. Humus content positively correlated with the tree vegetation. CCA analysis confirmed soil moisture (P<0.01) and herb layer (0-20 cm) (P<0.05) significantly affecting variations of ground beetle assemblages across the studied types of habitats. Another best variables selected by the forward selection were intensity of agrotechnical interventions, humus content and shrub vegetation. The CCA ordination plot (Figure 1) of the Carabidae species with weight and fit range from 5-100% and 5 environmental variables mostly affecting ground beetles assemblages variability across the studied types of habitats shoved following pattern: group of eleven mezohygrophilous, non-flying, silvicolous species preferring continuous forest stands, stable and natural habitats, was ordinated with the vector of humus, soil moisture and shrub vegetation. Although soil moisture neither humus correlated with the shrub vegetation, their highest values were assigned just across the shrub dominated sites. Except *Calathus melanocephalus* and *Carabus cancelatus*, species had the highest representation across the woody vegetation. Eight, xero till mezohygrophilous, macropterous species typicaly inhabitating fields, meadows or ruderals with herbage cover without any tree or shrubs, or indifferent to vegetation cover were ordinated to the vector of herb layer (0-20 cm) and had mostly the highest representation across the meadows. Exception concerned *Leistus ferrugineus*, mezohygrophilous species preferring herbage cover with dispersed group of trees and shrubs and *Pterostichus strenuus*, strongly hygrophilous species. Two species, *Calathus fuscipes* and *Cylindera germanica* were ordinate to the vector of intensity of agricultural interventions. Group of thirteen, mostly dry open habitat species, which dominated arable land was not directly ordinate to any of environmental variables monitored. The CCA ordination plot of the Carabidae species (Figure 2) is shoving the association of the habitat specialists - silvicolous species preferring continuous forest stands and association of the woody vegetation sites to the vector of shrub vegetation. Equally, the association of the particular study sites of the same habitat type to each other could be observed. Little exception concerned site SEal-2011 as well as SEw-2011.



▲-species, →-environmental variables, 3-shrub layer (50-400 cm above ground), 1 herb layer (0-20 cm above ground), W-soil moisture, INT-intensity of agrotechnical interventions; abbreviations of species: first two letters generic name, next two letters specific name. Abpa1-*Abax parallelus*, Abpa2-*Abax parallelepipedus*, Ptni1-*Pterostichus niger*, Opru1-*Ophonus rufibarbis*.

Figure 1. Five environmental variables mostly affecting ground beetles assemblages variability across the studied types of habitats

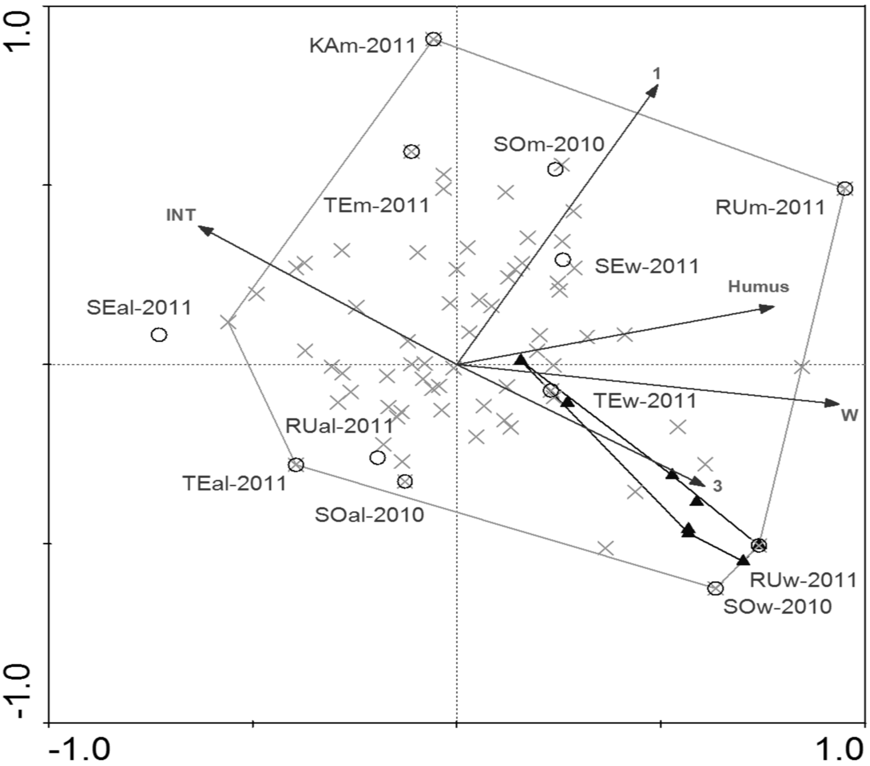


Figure 2. Association of the habitat specialists to the study sites

Discussion

Assemblages composition

Eudominant, dominant and subdominant species in this study, *Poecilus cupreus*, *Pterostichus melanarius, Pseudoophonus rufipes, Brachinus crepitans*, *Anchomenus dorsalis* and *Poecilus versicolor* were confirmed as the typical inhabitants of the various farmland habitats by the several authors too: Rivard (1966), Lovei (1984), Porhajašová et al. (2004), Bukejs and Balalaikins (2008), Porhajašová et al. (2008a, b), Bukejs (2009). *Poecilus cupreus* is characterised as the common, eurytopic species of the open habitats without shadowing, i.e. agroecosystems but equally occupying moderately humid habitats. *Pseudoophonus rufipes* is the mezohygrophilous species occupying dry and semi-humid habitats, i.e. fields, meadows, ruderals, with two reproduction cycles per vegetation season. *Brachinus crepitans* is the xerophilous inhabitant of the cultivated fields and steppes. *Anchomenus dorsalis* and *Poecilus versicolor* are typical for the open habitats with herbage cover without any tree or shrubs (Hůrka, 1996; Šustek, 2004). Contrary to their bionomy, species were confirmed as the dominant species even across the woody vegetation. According to Lovei (2008), fast-dwelling ground beetles typical for the arable land are not adapted on the leaf litter density and herb layer across the woody vegetation, what could inhibit them before the pervasion into such a type of habitat. But, obtained results are more closely to the Varchola and Dunn (2001) conclusions, that Carabids are able to migrate actively between the arable land and the non-crop habitats. Then, populations of particular farmland habitats can overlap and strongly affect each other. According to local conditions, they just change their range in particular assemblages (Porhajašová et al., 2008b).

No significant differences were confirmed between the studied types of habitats in the taxonomic richness, diversity, evenness or dominance. Only significant distinction concerned the number of entrapped individuals and activity abundance. Nevertheless, some regular trends were observed: arable land was characterised by the huge number of individuals entrapped, the species richness exceeded those of the semi-natural habitats included in the study. But, assemblage had the lowest diversity, evenness and highest dominance. The strong anthropogenic disturbances repeated periodically during the growing season support the survival of the fast-dwelling zoophagous groups, i.e. massive dominance of Carabidae family able to avoid the detrimental effect of the agrotechnical actions. Arable land ground beetle community is then characterised by the dominance of low number of euconstant species with eudominant and dominant representation and huge number of individuals entrapped (Baguette and Hance, 1997; Fournier et al., 1998). Community is supplemented by high number of additional, accidentally occurring species with the subdominant, recedent and subrecedent representation and low number of individuals entrapped. The assemblage is low diversified and with the low evenness. The exception concerned site SEal-2011, when assemblage shoved the diversity and evenness comparable to those of meadows and woody vegetation sites could be explain as follows: across the site, the traps were placed in very close proximity to electric pylons, trying to avoid the so-called ”lost of traps” in the homogeneous arable land and damage to them caused by ploughing or harvesting. Because of practical reasons, these agricultural actions could not be provided near the bottom of the pylons. So there remain small a–spots with proved vegetation. Such a micro habitat can provide environmental conditions similar to those of semi natural and natural habitats, for example field boundaries or woody vegetation, thus supporting survival of more stenotopic species or habitat specialists. Then, dominance is distributed between the higher number of taxa, community became more diversified and with the high evenness (Baranová and Fazekašová, 2012). This phenomenon could be used also to explain remarkable high activity abundance of *Leistus ferrugineus*, mezohygrophilous species preferring herbage cover with dispersed group of trees and shrubs recorded across the meadow site KAm-2011. Quantitative representation of the *Bembidion tetracolum*, *Brachinus crepitans, Nebria brevicollis*, *Platyderus rufus*, *Pterostichus anthracinus*, *P. niger*, *P. oblongopunctatus* and *P. strenuus* across the Site TEw-2011 was probably caused by the site position within the moistened terrain depression.

Concerning habitat preferences, ability to fly and body size, obtained results are in accordance with following conclusions: flying ability and ecological tolerance are the important factors affecting the ground beetle species intro mission into the strongly disturbed habitats (Šustek, 1981). The agrotechnical actions apparently conform the species with the high dispersability, preferring habitats with low humidity of environment (Holland and Luff, 2000; Rainio and Niemelä, 2003; Porhajašová et al., 2004). Arable land and meadows assemblages are then characteris ed by the number of small macropterous generalists. With the decreasing measure of anthropogenic interventions, number of large and wingless habitat specialists increase (Ishitani et al., 2003; Rainio and Niemela, 2003; Small et al., 2003; Magura et al., 2008). Woody vegetation apparently supports the survival of more stenotopic species (Fournier et al., 1998; de la Peña et al., 2003; Olechowicz, 2007) and its contribution to farmland diversity is higher than those of grass fields or arable land (Varchola and Dunn, 2001). Woody vegetation may also serve as very important over wintering site, spring refuge for Carabidae and so supply ground beetles during the early growing season (Pfiffner and Lukka, 2000; Varchola and Dunn, 2001; Maudsley et al., 2002). That could partially explain the phenomenon concerning the drift of seasonal activity recorded in this study.

Environmental variables

CCA confirmed variations in the ground beetles' assemblages between the studied farmland habitats in relation to soil moisture and herb layer (0-20 cm). Although any significant distinctions were confirmed between the habitats in the soil moisture, following pattern was observed: the woody vegetation proved the highest soil humidity, soil moisture decrease toward to meadows and arable land consequently. Equally, it was confirmed, that the soil moisture decrease as the intensity of agrotechnical interventions increase. Thus the harvesting or ploughing expose the present soil fauna to risk of desiccation (Barker et al. 1999). Nor significant correlation between the vegetation cover structure and soil moisture neither significant differences between the habitats in the vegetation cover were observed. But, it is without doubt, that the vegetation cover structure apparently affects the soil moisture. Arable land is after the crop without the permanent plant coverage throughout the most part of the year. Crop-plant cover changes its structure during the growing season, thus, the soil shadowing, heating and water evaporation change dramatically. In opposite, the soils under shrubs acquired and retained soil moisture resources more efficiently than the other cover types (Wang et al., 2012).
Then, woody vegetation support more efficient shadowing, reduce evaporation and soil heating (Šustek, 2004). Although any correlations between the environmental variables and the coenological characteristics were observed, Shannon index indicating, that the non-crop, woody vegetation habitats with the highest soil moisture, water retention capacity, bulk soil moisture, porosity, organic carbon and humus content and in opposite with the lowest intensity of the agricultural interventions had the highest diversity (Veselý and Šarapatka, 2008; Sadej et al., 2012).

Conclusions

The soil moisture is found to be one of the main factors affecting carabid adults as it was confirmed in this study too. Also it is obviously in this case, that the humidity affects the variations in the Carabidae assemblages across the studied types of farmland habitats in complex with the vegetation cover structure and intensity of agrotechnical interventions. Equally, it could be concluded, that the other from selected soil properties have just secondary meaning for distribution of the adult carabids across the arable land, meadows and woody vegetation. Obtained results also indicate, that the environmental variables have the strongest effect on those of ground beetles, which have the special requirements to the environment quality, i.e. habitat specialists. Whereas the generalist carabids seem to be affected by the environmental variables studied just little. It enables them to occupy wide spectrum of habitats with different quality and to dominate across the most of farmland habitats. Whereas the agricultural land is characterised by the huge dominance of small macropterous generalists, the large wingless habitat specialist survives within the rest of the natural and semi natural, non-crop habitats. The detailed understanding of soil fauna distributions across the farmland habitats might be used for: more effective management leading to higher level of farmland diversity, minimisation of the detrimental effects of agricultural interventions on edaphic fauna, optimisation of the non-crop habitats management, for manipulation of agricultural landscapes in ways that enhance of population size and survival and benefit predatory invertebrates by providing alternate food sources, over wintering sites and refuge from farming activities.

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