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Assemblages of ground beetles (Carabidae, Coleoptera) in peatland habitat, surrounding dry pine forests and meadows

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Abstract
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This research was conducted to study assemblages of ground beetles in peatland, surrounding dry pine forests and meadows in the Šuja peatbog (in northern part of Slovakia) in 2013. The main aim was to classify assemblages of beetles into different habitat types, compare their composition and analyse the relation of species occurrence at study sites. Carabids were sampled between May and October 2013 at 8 study sites using pitfall traps and 1,627 individuals belonging to 55 species were registered in total. All features such as diversity, equitability, species composition, their preference for humidity and vegetation cover, inclusion in the group of their ecological valence and habitat association and community index of the ground beetles were used to characterize ground beetle communities at each study site. In order to evaluate the relationship among the communities of the carabid beetles at the sampling sites we used principal component analysis. The scatter of species formed four groups of species associated with dry open lowland habitats, wetter woodland habitats, hygrofil wetland habitats and dry to semi wet unshaded habitats.

Key words
assemblages, ground beetles, peatland, forests, meadows

Introduction

Peatlands and other wetland ecosystems play an important part in European biodiversity. They provide ideal conditions for a considerable diversity of habitats and species (EC, 2007). Peatlands are very rare, endangered and often relict ecosystems. In general, there is a lack of knowledge about ecosystem functioning and management planning and not all protected areas in Slovakia are protected effectively (Stanová, 2000). Some peatlands have been preserved in a natural state, but most of them have been drained and became highly fragmented, isolated or naturally overgrown by forest. Therefore peatlands and other wetland fragments are mainly surrounded by drier habitats such as forests or meadows.

The environmental sensitivity of peatlands makes insects valuable as bioindicators. With increasing scientific interest in peatland insects and the fact that each relict peatland habitat island is unique, further studies of the diversity of peatland fauna are very important and the conservation of these habitats should be strongly supported (Spitzer and Danks, 2006).

This paper deals with description of ground beetles species composition and characteristics in peatland habitats surrounding dry pine forest and meadows near Šuja peatbog.

According to the range of ecological valence and association with habitat the ground beetles present in Slovakia are divided into three groups: R (relict), A (adaptable), E (eurytop), (Hůrka et al., 1996, Farkač et al., 2007). The fauna of original or little disturbed natural habitats is always composed mostly of A-species as well as some R-species, while E-species are scarcely represented. The number of E-species is in-

creasing with deterioration of the environment (Farkač et al., 2007).

Majority of published research studies refer only marginally to this territory. That applies to invertebrates as well as to other animals. Vertebrate fauna has been researched here by Bitušík and Bitušík (1995). Bitušík (1998) has obtained data of midges fauna (Chironomidae) in the waters of Šujska peatbog. Beetle communities on this site were analyzed by Majzlan et al. (2004).

Study area and sampling sites

The Šuja peatbog nature reserve is subject to 4th level of nature protection (10.8 ha). It is also Special Area of Conservation (SAC), which belongs to the NATURA 2000 network (13.48 ha) located at altitude 470 m. During the 1970s, the territory was destroyed by peat exploitation mainly its northwestern part. Nevertheless, it is still an important wetland area of Slovakia, but there is a threat in increasing succession. *Pinus nigra* is spreading on the northwestern part from the surrounding dry pine forest and more willow shrubs spread to the centre of the peatbog from the east part of Rajčianka riverside. The exploited area is being gradually overgrown by original and ruderal vegetation. In the Šuja peatbog there is an „island" where *Rubus* sp., *Urtica* sp. appears. This part is influenced by the decline of groundwater level. The edges of neighboring roads are surrounded by trees (*Salix* sp., *Alnus glutinosa*). There is a dense stand of reeds in the northwestern part and eastern part of the territory (*Phragmites* sp.).

Eight sampling sites of peatbog habitats, surrounding dry pine forest and meadows were established (Fig 1):

1 (49°03'40.4"N, 18°36'57.2"E), dry pine forest – forest edge at slope of Strážov hills on the limestone ground with *Pinus* sp.
2 (49°03'37.7"N, 18°36'58.6"E), osier – waterlogged area at mild depression with *Salix repens* and *Salix purpurea*
3 (49°03'37.6"N, 18°37'02.1"E), playground – meadow, mown area, flat surface, without trees, slightly dry, with frequent appearance of molehills
4 (49°03'40.3"N, 18°37'05.2"E), peat – peat bench, unexploited part of peatland, with *Rubus idaeus*
5 (49°03'42.6"N, 18°37'05.8"E), gravel bars – gravel bench in the middle of the reservation with *Betula* sp. and *Pinus* sp.
6 (49°03'44.6"N, 18°37'05.8"E), reed – damp areas around slightly flowing water with *Phragmites australis*
7 (49°03'46.3"N, 18°37'09.8"E), overgrowth – on the peat bench with *Salix* sp. and *Rubus* sp.
8 (49°03'36.9"N, 18°37'18.4"E), field-meadow-edge of the meadow and field by the Rajčianka riverside, ruderal, overgrown with vegetation.

Material and methods

The ground beetles were pitfall-trapped during the year 2013 regularly in bi-weekly intervals (on following dates: 3 May, 17 May, 2 June, 16 June, 1 July, 15 July, 29 July, 12 August, 27 August, 14 September, 27 September, 12 October and 1 November 2013) at eight sampling sites. Pitfall traps were installed on 14 April 2013 and exposed for 201 days. Covered traps (500 ml in size, 10 cm in diameter, half-filled with 4% formalin solution) were used to collect samples. Five traps were placed in lines in each habitat. The carabid beetle individuals were identified using keys of Trautner and Geigenmüller (1987) and Hůrka (1996). Characteristics of the environment requirements of species were according to works of Roubal (1930), Nakládal and Hejda (2012) and Šustek (2012, 2010, 2004, 2000). The humidity preference was classified using an eight degree semiquantitative scale (1 – strongly xerophilous, 4–5 mezohygrophilous, 8 – strongly hygrophilous) and preference of the ground beetles for vegetation cover with a five degree semiquantitative scale 1–5 (1 – open landscape species (fields, meadows, ruderals), 2 – indifferent to vegetation cover (eurytopic in largest sense), 3 – herbage cover with disperged group of trees or shrubs, 4 – forest species, 5 – rupicolous species) (Šustek, 2004). As a diversity index, the Shannon-Wiener index (H') (Shannon and Weaver 1949; Spellerberg and Fedor, 2003), which is a commonly used diversity index considering both abundance and evenness of species present in the community, was chosen. As an equitability index we used Pielou's Evenness Index or Equitability (E) (Pielou, 1966). All these calculations were carried out using the PAST program. The ground beetles were divided into three groups: R (relict), A (adaptable), E (eurytop) according to the range of their ecological valence and their association with the habitat of Farkač et al., 2007. Based on this species distribution and mathematical model of Boháč (1990), the stage of antropogenetic degradation maybe characterized by a community index of the ground beetles (IKS) (Nenadál, 1998). This index proposes 5 levels of anthropogenic degradation in total: 1 – deeply affected (value 0–15), 2 – strongly affected (value 10–35), 3 – affected (value 30– 50), 4 – slightly affected (value 45–65), 5 – unaffected (value 65–100). Principal component analysis (PCA) was conducted to evaluate the relationship among the communities of the carabid beetles at the sampling sites using the CANOCO software program (TerBraak and Šmilauer, 1998). The longer a single arrow is, the higher the value of single species within the sampling site around them. Though smaller distance between arrow and axis represents a higher correlation between the two values.

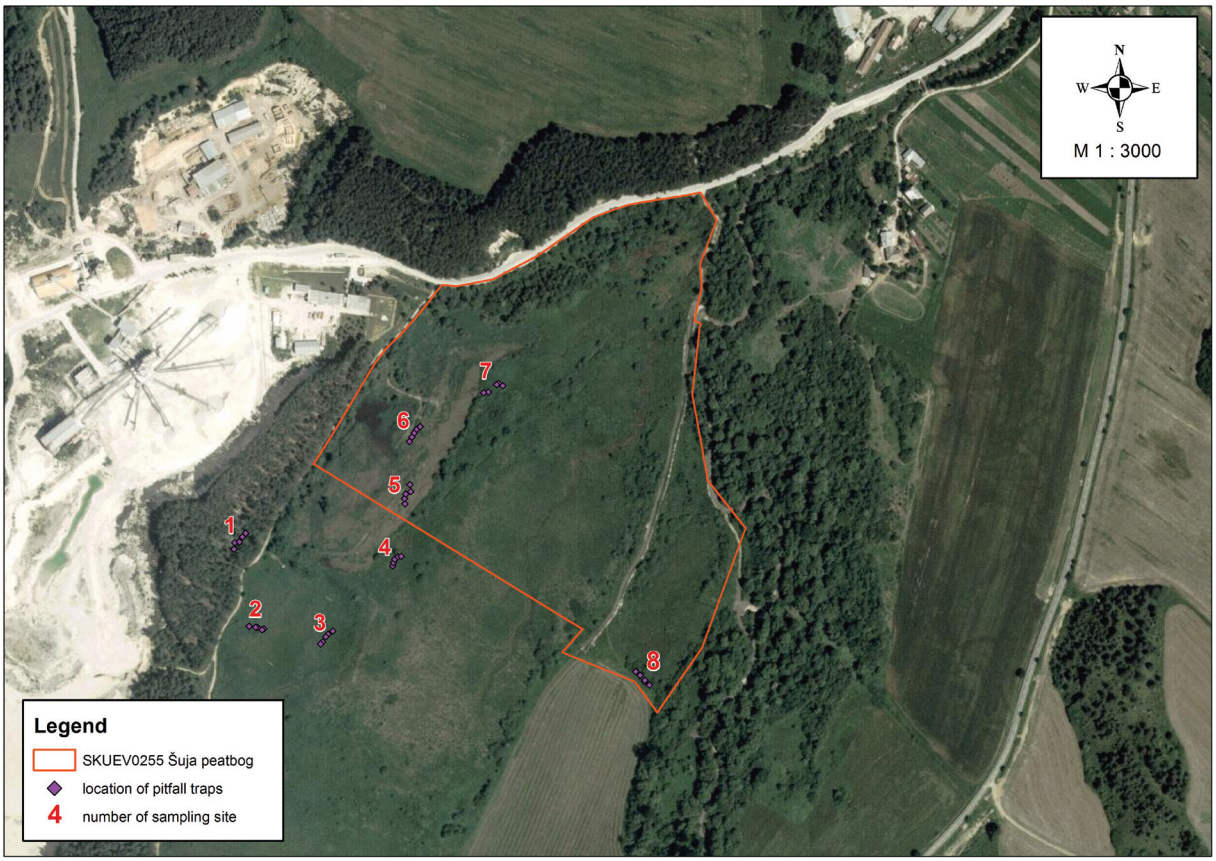

Fig. 1. Distribution of sampling sites in the Šuja peatbog.

Results and discussion

A total of 1,627 individuals belonging to 55 species were registered (Table 1) and all sampling sites demonstrated the high dominance of *Poecilus versicolor* and *Poecilus cupreus*.

Eudominant species (>10%) occur in the forest such as *Abax parallelepipedus* (31.2%), *Carabus violaceus* (23.65%) and *Molops piceus* (12.9%). *Abax parallelepipedus* occurs in wooden habitats and is often a dominant species within forest communities. *Carabus violaceus* and *Molops piceus* prefer shaded habitats and are more or less mezohygrophilous species.

The osier has a balanced dominance of *Pterostichus niger* (27.7%) and *Pterostichus diligens* (17.85%). These species prefer wet and semi-wet places from lowlands to mountains and are also present in other study sites.

The highest number of individuals was recorded at the playground, with three eudominant species *Poecilus versicolor* (22.53%), *Poecilus cupreus* (15.11%) and *Amara communis* (10.25%). *Poecilus versicolor* and *Poecilus cupreus* are eurytopic species, inhabiting unshaded habitats, meadows, fields and ruderal habitats. *Amara communis* prefers open habitats e.g. fields, abandoned fields, managed meadows.

The peat had a balanced representation of two eudominant species *Carabus ullrichi* (24.9%) and *Pterostichus melanarius* (13.83%). These species are mezohygrophilous. However *Pterostichus melanarius* is eurytopic and appears in the fields, meadows, gardens, open lands from lowlands to uplands and *Carabus ullrichi* prefers woodland habitats.

Low number of species following three eudominant species was found in the gravel bars: *Poecilus versicolor* (17.3%), *Amara lunicollis* and *Carabus coriaceus* (13.04%). The first two are heliofil species which prefer unshaded habitats with preference for drier ones. *Carabus coriaceus* is mezohygrophilous forest species.

The reeded area was characterized by eudominant species *Pterostichus diligens* (38.9%), *Pterostichus niger* and *Trechussecalis* (13.8%). *Pterostichus diligens* is eurytopic and *Pterostichus niger* prefers woodland habitats. All these species are hygrofilous. *Trechussecalis* is present in marshes and bogs.

In the overgrowth site *Trechus secalis* (21.25%) and *Patrobus atrorufus* (11.8%) were dominant. In general *Patrobus atrorufus* prefers humid and woodland habitats and occurs only at this site.

Finally, in the field-meadow, the dominant species were *Poecilus cupreus* (19%), *Abax parallelepipedus* (13.63%), *Carabus ullrichi* and *Poecilus versicolor*

Table 1. Abundance of ground beetles (Carabidae) sampled

Species	Abbr	PH	VC	for	osi	plg	pet	gra	ree	ovg	fim
Abax parallelepipedus (Piller et Mitterpacher., 1783)	Abpa	3	4	29	2	1	6	0	0	3	33
Agonum fuliginosum (Panzer, 1809)	Agfu	8	4	0	5	2	2	0	0	1	0
*Agonum sexpunctatu*m (Linnaeus, 1758)	Agse	5	1	0	0	1	0	0	0	1	0
*Amara aulic*a (Panzer, 1797)	Amau	3	1	0	0	0	0	0	0	15	0
Amara communis (Panzer, 1797)	Amco	–	–	0	0	76	8	2	0	1	0
Amara familiaris (Duftschmid, 1812)	Amfa	3	1	0	0	6	0	0	0	1	1
*Amara lunicolli*s (Schiődte,1837)	Amlu	–	–	0	1	55	10	3	3	4	0
Anchomenus dorsalis (Pontoppidan, 1763)	Ando	3	1	0	0	0	0	0	0	0	1
Anisodactylus signatus (Panzer, 1797)	Ansi	5	1	0	0	0	0	0	0	0	2
Badister sodalis (Duftschmid, 1812)	Baso	7	2	0	1	1	0	0	0	0	0
Bembidion mannerheimi (Sahlberg, 1827)	Bema	8	4	0	2	46	5	0	0	2	1
Bembidion properans (Stephens, 1828)	Bepr	3	1	0	1	3	0	0	0	0	1
Bradycellus caucasicus (Chaudoir, 1846)	Brca	3	1	0	1	4	2	0	0	0	0
Calathus fuscipes (Goeze, 1777)	Cafu	4	1	0	0	1	0	0	0	0	0
Calathus micropterus (Duftschmid, 1812)	Cami	–	–	0	0	1	0	0	0	7	0
Carabus convexus (Fabricius, 1775)	Caco	4	4	3	0	33	11	1	0	0	4
Carabus coriaceus (Linnaeus, 1758)	Caco2	5	4	2	2	0	13	3	0	5	6
Carabus granulatus (Linnaeus, 1758)	Cagr	7	2	1	10	3	3	0	2	0	6
Carabus intricatus (Linnaeus, 1761)	Cain	4	4	2	0	0	0	0	0	0	0
Carabus problematicus (Herbst, 1786)	Capr	4	1	4	0	0	0	0	0	0	0
Carabus ullrichi (Germar, 1824)	Caul	4	4	3	7	22	63	0	1	2	28
Carabus violaceus (Linnaeus, 1758)	Cavi	5	4	22	5	16	13	1	0	2	4
Clivina collaris (Herbst, 1784)	Clco	6	2	0	1	5	0	0	0	0	1
Cychrus caraboides (Linnaeus, 1758)	Cyca	5	4	2	0	0	0	0	0	0	0
Dyschirius globosus (Herbst, 1783)	Dygl	8	5	0	0	5	2	0	0	1	1
Harpalus latus (Linnaeus, 1758)	Hala	4	1	0	0	0	0	3	1	1	6
Lebia chlorocephala (Hoffmann, Koch, P. Műller et Linz, 1803)	Lechl	4	4	0	0	1	0	0	0	0	0
Leistus ferrugineus (Linnaeus, 1758)	Lefe	4	3	1	0	18	0	0	0	0	0
Leistus terminatus (Hellwig in Panzer, 1793)	Lete	5	4	0	0	34	1	0	0	3	5
Molops piceus (Panzer, 1793)	Mopi	4	4	12	0	0	0	0	0	0	0
Nebria brevicolis (Fabricius, 1792)	Nebr	6	2	0	0	2	2	0	0	0	5
Notiophilus palustris (Duftschmid, 1812)	Nopa	4	2	1	0	1	1	0	0	2	11
Oodes helopioides (Fabricius, 1792)	Oohe	8	2	0	1	0	1	0	0	0	1
Ophonus azurens (Fabricius, 1775)	Opaz	2	1	0	0	1	0	0	0	0	0
Panagaeus bipustulatus (Fabricius, 1775)	Pabi	4	1	0	0	1	0	0	0	1	0
Paradromius linearis (Olivier, 1795)	Pali	2	1	0	0	0	1	0	0	0	0
Patrobus atrorufus (Stroem, 1768)	Paat	7	4	0	0	0	0	0	0	15	0
Platynus assimilis (Paykull, 1790)	Plas	7	4	0	0	0	1	0	0	0	0
Poecilus cupreus (Linnaeus, 1758)	Pocu	4	1	0	1	112	9	2	0	1	46
Poecilus versicolor (Sturm, 1824)	Pove	2	1	0	1	167	8	4	2	0	28
Pseudoophonus rufipes (De Geer, 1774)	Psru	4	1	0	0	2	0	0	0	1	7
Pterostichus anthracinus (Illiger, 1798)	Ptan	8	4	0	0	0	1	0	0	0	9
Pterostichus burmeisteri (Heer, 1841)	Ptbu	5	4	0	0	0	1	0	0	0	0
Pterostichus diligens (Sturm, 1824)	Ptdi	7	2	2	20	29	13	0	14	6	1

Table 1. Abundance of ground beetles (Carabidae) sampled – continued

Species	Abbr	PH	VC	for	osi	plg	pet	gra	ree	ovg	fim
Pterostichus melanarius (Illiger, 1798)	Ptme	5	2	0	2	52	35	0	0	12	17
Pterostichus minor (Gyllenhal, 1827)	Ptmi	8	5	0	2	0	0	0	0	0	0
Pterostichus niger (Schaller, 1783)	Ptni	6	4	8	31	5	6	3	5	5	5
Pterostichus nigrita (Paykull, 1790)	Ptni2	8	2	0	0	1	1	0	1	2	6
Pterostichus oblongopunctatus (Fabricius, 1787)	Ptob	5	4	1	0	0	0	0	0	0	1
Pterostichus ovoideus (Sturm, 1824)	Ptov	4	2	0	10	8	23	1	2	5	5
Pterostichus strenuus (Panzer, 1797)	Ptst	7	2	0	0	1	0	0	0	0	0
Pterostichus vernalis (Panzer, 1796)	Ptve	8	5	0	0	1	0	0	0	0	0
Stomis pumicatus (Panzer, 1796)	Stpu	6	2	0	0	2	0	0	0	0	0
Syntomus truncatellus (Linnaeus, 1761)	Sytr	4	1	0	0	0	3	0	0	1	0
Trechus secalis (Paykull, 1790)	Trse	–	–	0	6	22	8	0	5	27	0

Abbr, Abbreviations; PH, preference for humidity: scale 1–8 (1 – strongly xerophilous, 4–5 mezohygrophilous, 8 – strongly hygrophilous); VC, vegetation cover preference: scale 1–5 (1 – open landscape species (fields, meadows, ruderals), 2 – indifferent to vegetation cover (eurytopic in largest sense), 3 – herbage cover with dispersed group of trees or shrubs, 4 – forest species, 5 – rupicolous species); for, forest; osi, osier; plg, playground; pet, peat; gra, gravel bars; ree, reed; ovg, overgrow; fim, field-meadow.

(11.6%). The first and last prefer dry open habitats. *Carabus ullrichi* is mezohygrophilous and woodland similarly as *Abax parallelepipedus*.

The results show that the number of species registered in the studied sites was the same in the gravel bars and reed (10). The highest number of individuals (741) refers to the playground, however the equitability reaches its minimum (0.7279). The lowest number of individuals was located in gravel bars (23) and reed (36). The gravel bars show the highest value of equitability (0.9557). The highest diversity index was at the overgrown sampling site (2.737) (Table 2).

During the sampling period no R-species were recorded in all localities. A- and E-species were observed at all localities in different ratios. 22 (59.5%) adaptable and 15 (40.5%) eurytopic species were recorded in the playground. 13 (81.25%) adaptable and 3 (18.75%) eurytopic species were recorded in the forest. 14 (51.8%) adaptable and 13 (48.2%) eurytopic species were recorded in the field-meadow. 7 (70%) adaptable and 3 (30%) eurytopic species were recorded in the reeds. 20 (69%) adaptable and 9 (31%) eurytopic species were recorded in peat. 18 (66.7%) adaptable and 9 (33.4%) eurytopic species were recorded in the overgrown site. 8 (80%) adaptable and 2 (20%) eurytopic were found in the gravel bars. 14 (70%) adaptable and 6 (30%) eurytopic species in the osier. The highest IKS index values were in the forest and gravel bar study sites and the lowest ones at the field-meadow and playground study sites.

The IKS index may be sometimes confusing as E-species occur in all habitats but also in anthropogenetic uninfluenced ones. In contrast R-species are found only in the anthropogenetic uninfluenced habitats.

Principal component analysis (PCA)

The PCA ordination diagram of the carabid beetle communities at 8 sampling sites is represented in Figure 2. Eigenvalues of the two first axes are $\lambda 1 = 0.83$ and $\lambda 2 = 0.078$. The first canonical axes account for 83% of the total variance of the species data. The scatter of species forms four groups (Fig. 2).

The scatter of carabid beetle species and sampling sites form four groups (Fig. 2). The first group contains species *Paradromius linearis, Syntomus truncatellus,*

Table 2. Diversity and equitability

	for	osi	plg	pet	gra	ree	ovg	fim
Number of species	15	21	37	29	10	10	27	28
Number of individuals	93	112	741	253	23	36	127	242
Diversity (H')	2,062	2,399	2,628	2,694	2,201	1,903	2,737	2,705
Equitability(E)	0,7613	0,7879	0,7279	0,8	0,9557	0,8265	0,8304	0,8118
Index of ground beetles community (IKS)	40,63	35	29,73	34,49	40	35	33,33	25,93

for, forest; osi, osier; plg, playground; pet, peat; gra, gravel bars; ree, reed; ovg, overgrow; fim, field-meadow.

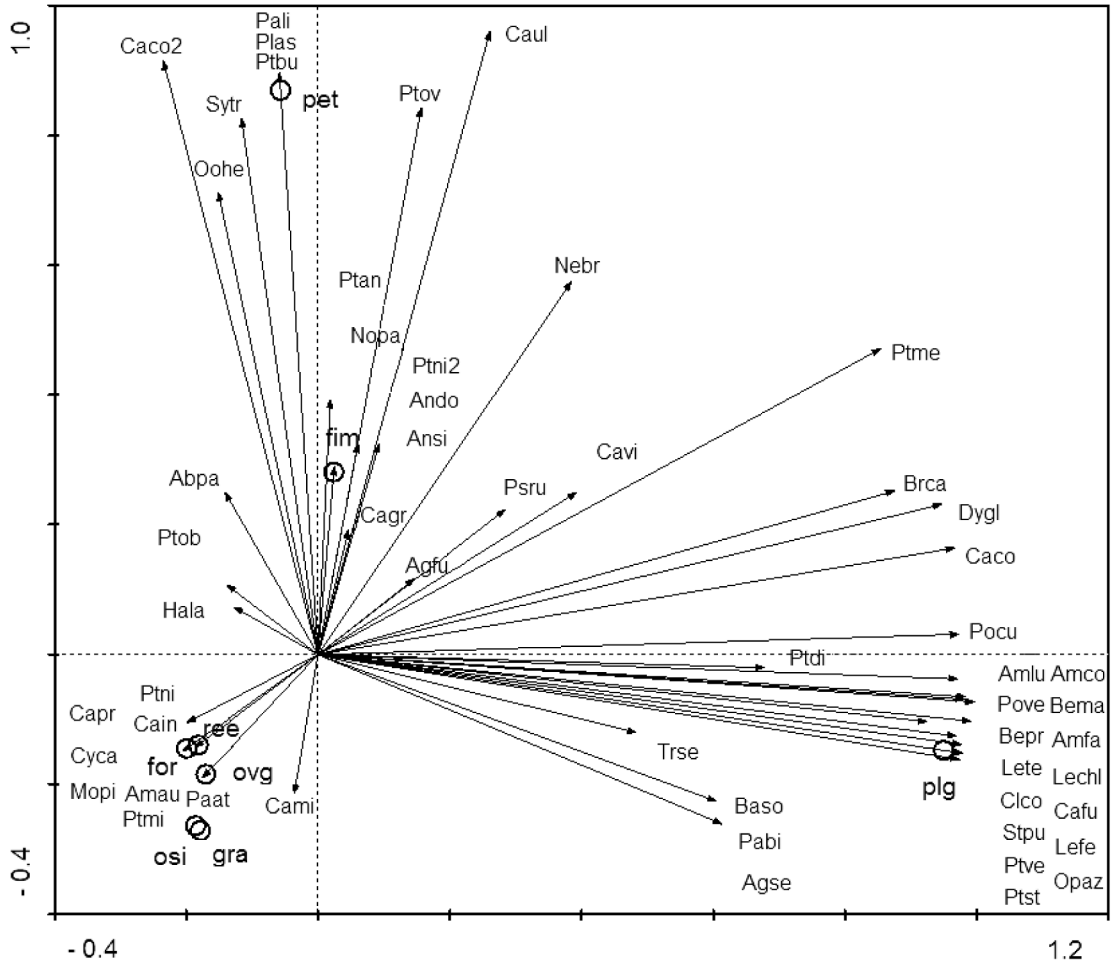

Fig. 2. Ordination diagram based on Principal Component Analysis (PCA) of carabid beetle species and sampling sites. The species are represented by arrows. For abbreviations of species names see the Table 1. Codes of study sites: plg, playground; for, forest; fim, field-meadow; osi, osier; pet, peat; ovg, overgrow; gra, gravel bars; ree, reed.

Carabus coriaceus, Carabus ullrichi. Paradromius linearis and *Syntomus truncatellus* are associated with dry, more xerophilous open non-forest habitats in lowlands and ruderal habitats, fields or vineyards. *Carabus coriaceus* and *Carabus ullrichi* are mezohygrophilous and forest species (the upper right quadrat and upper left quadrat of the ordination diagram). Species associated with dry, xerophilous non-forest habitats, but also species associated with more humid woodland habitats had a closer relation with peat sampling site.

The second group contains species *Carabus problematicus, Cychrus caraboides, Molops piceus, Carabus intricatus, Abax parallelepipedus, Pterostichus oblongopunctatus* associated with mezohygrophilous forest habitats with temporary covers (the lower left quadrat and upper left quadrat of the ordination diagram). Species associated with more or less mesophilic shaded forest habitats had relation with the forest in the peat vicinity.

The third group contains *Trechus secalis, Pterostichus diligens* and *Badister sodalist* associated with strongly hygrophilous habitats, near waters, wet habitats, peatbogs and wetlands and *Patrobus atrorufus, Pterostichus minor* associated with strongly hygrophilous habitats (the lower left quadrat and lower right quadrat of the ordination diagram). Species associated with hygrophilic habitats occurred in the gravel bars, osier, reeds and overgrowth, but also in the playground.

The fourth group contains *Poecilus versicolor, Poecilus cupreus, Bembidion properans* and *Amara communis* associated with unshaded habitats, more dry to semi wet and open lowland habitats (the upper right quadrat and lower right quadrat of the ordination diagram). Species associated with dry to semi wet and unshaded habitats occurred in the playground and field-meadow. These characteristics of carabid beetles are known; also the result of the analysis demonstrated them.

Carabus intricatus according to IUCN (2013) belongs to lower risk (LR) or near threatened (NT) IUCN threat status. Remaining carabid beetles in the sample had not evaluated (NE) IUCN threat status. *Carabus intricatus* was found in the forest.

Carabus problematicus belongs according to Annex no. 6 to Decree no. 24/2003 Coll. implementing the Law no. 543/2002 Coll. on nature and landscape protection to the list of species of national importance. *Carabus problematicus* was found in the forest. From the nature protection point of view valuable species occurred at the forest sampling site.

Pterostichus diligens is considered to be a tyrphophilous carabid species (Spitzer et al., 1999) and it was dominant at reed and osier sampling sites occurring at gravel bars, osier, reed, overgrowth and also with playground sampling sites.

The most ecosozological value according to the ratio of the adaptable and eurytop species percentage and IKS index values, was found in the forest and gravel bars. In addition, the gravel bars sampling site also indicates the highest value of equitability. The highest diversity index was at the overgrowth sampling site.

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