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Grasslands with calcareous gyttja soil in the Olsztyn Lake District as specific habitats for ground beetles (Coleoptera: Carabidae)

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The aim of the present paper was to determine the species composition and structure of carabid beetle assemblages found in carbonate-rich soils. The sites chosen for analyses lie on the bottom of a former ribbon lake that used to connect two lakes. The study was carried out in Northeastern Poland near Olsztyn in 2013. Two areas (with two sites distinguished in mentioned areas) were selected for the observations: an extensively used meadow and the agricultural wetland being transformed to bog. A total of 1573 individuals, representing 39 species, were captured in pitfall traps. The results reveal that grasslands located on carbonate soils, especially those excluded from agricultural use, are a source of valuable and rare species of Carabidae and such kind of sites should be subject to special monitoring. Furthermore it was found that factors which most probably differentiated the species composition of carabid beetles on calcareous grasslands were: different land use, changeable moisture conditions and the presence of forests in the surrounding of the habitats.

Key words: carabid beetles, assemblages, carbonate soils, life traits

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INTRODUCTION

One of the peculiarities of the young glacial lacustrine landscape are gyttja deposits formed as a result of the draining of a lake. The practice, intensive at the turn of the 19th and 20th centuries, was aimed at increasing the amount of grassland (Arend 189; Piaścik & Lemkowska 2004). Lake bottoms were transformed into agricultural land. As a result, the dried lake was transformed into an area filled with calcareous gyttja (Meller 2006, Lemkowska & Sowiński 2008). The calcareous gyttja soils as described in the paper are very rare. We can find them in

Poland and Germany. Mückenhausen (1962) called them 'graubraune Mullrendzina', in Poland they were named 'quartenary rendzina' or 'post-lake rendzina' (Uggla 1976). According to World Reference Base for Soil Resources (WRB 2006) different types of these soils are classified as Sapric Limnic Histosols Hypercalcaric, Limnic Histosols (Calcaric), Gleyic Rendzic Leptosols (Meller et al. 2009), Saprihistic Gleysol, Mollic Limnic Fluvisol (Calcaric) (Bartkowiak & Długosz 2011). The hydrological characteristics of these sites expose them to effects produced by groundwater throughout most of the year and to flooding in autumn, winter and spring. These effects are manifested by the high soil moisture content, which in turn affects the air, water and thermal conditions. This distinguishes lacustrine rendzina from rendzina soils developed from solid limestone, which are warm, permeable and dry soils (Kuźnicki 1976; Uggla 1976). The two types of soil create different conditions for the development of plants and, consequently, for the accumulation of organic matter or presence of insects associated with these soil habitats. The lack of available information about the Carabidae dwelling in such habitats has encouraged us to undertake the present study.

Carabidae, due to sensitivity to changing environmental conditions and their prevalence and ease with which they can adapt, constitute one of the important bioindicators used in environmental research (Rainio & Niemelä 2003; Koivula 2011; Kotze et al. 2011; Schwerk & Szyszko 2011; Skłodowski 2014a). Many researchers in Europe and worldwide have worked on changes in Carabidae assemblages inhabiting various types of grasslands. Due to the preservation of high levels of biodiversity, among others of Carabidae, the high environmental value of the following was emphasized: dry meadows (Ödman et al. 2011; Venn et al. 2013; Pietzsch et al. 2013; Schirmel et al. 2015), fresh meadows of various degrees of moisture (Thiele 1977; Czechowski 1989; Huruk 2003, 2006; Huruk & Huruk 2004; Nietupski et al. 2007; Andersen 2011; Lafage & Pétillon 2014), wet meadows or periodically flooded grasslands (Zulka 1994; Lambeets et al. 2008; Lik 2010; Porhajašová et al. 2010; Do et al. 2012; Sienkiewicz & Zmihorski 2012; Schirmel et al. 2014; Skalski et al. 2012; Williams et al. 2014). Apart from hydrological conditions, close attention was paid to the types of use of meadows, grazing, mowing or fertilisation (Sienkiewicz 2003; Grandchamp et al. 2005; Cole et al. 2010; Moran et al. 2012; Wamser et al. 2012; Williams et al. 2014) on Carabidae assemblages. However, the issue of Carabidae groups in such habitats as supra-cretaceous grasslands remains poorly explored. In general, those habitats, despite their high environmental value, have been insufficiently studied. In Poland, Ruta (2013) worked on the characteristics of flora and fauna of supra-cretaceous grasslands, but data concerning insects are very fragmentary. In southern Britain, lowland calcareous grasslands were investigated by Mortimer et al. (1998, 2002). They described the interactions between the vegetation of the investigated habitats and the biodiversity of insects, including Carabidae. However, the carabid fauna of this type remains poorly explored, therefore it is justified to conduct this type of research.

The aim of this study was to determine the species composition and structure of assemblages of ground beetles on carbonate-rich soils. An attempt was also made to evaluate which ecological factors (land management, moisture conditions and the presence of forests and arable fields in the surrounding of the studied areas) have influence on the ground beetle assemblages and determine some of their life history traits.

MATERIAL AND METHODS

Study area

The study was conducted in Northeastern Poland in the Olsztyn Lake District, in the moraine landscape of the Pomeranian phase of Vistulian Glaciation. The sites chosen for analyses lie on the bottom of a former ribbon lake that used to connect Wulpinskie Lake with Gilwa Lake. This water body was drained at the turn of the 19th and 20th century as part of a large-scale hydro-engineering project carried out in the whole region of the Masurian Lakes, where water from shallow water bodies was removed in order to enlarge the total acreage of grasslands. The peculiarities of this soil are its high content of calcium carbonate ($CaCO_3$) – in this case, lacustrine chalk, high pH (7.6–8.1), and a white-grey colour (Lemkowska & Sowiński 2008).

Two areas were selected for the observations, and two sites were distinguished in both areas: one on an extensively used meadow (M1, M2), and the other one on some wetland (W1, W2). We used the term wetland because it is a wider concept that reflects the evolution of a habitat in different directions (Maltby & Barker 2009; Mitsch et al. 2009). The described habitat is in the initial phase of the transformation to fen (Hăjek et al. 2006). Research objects W1 and W2 are located in the peripheral part of the drained lake. In the vicinity exploitation of lacustrine chalk was carried out. The old excavation again turned into a lake, and the higher ground in calcareous wetland. At the surface horizon of the object W1 22% $CaCO_3$ was found and in the object W2 38%. On the bottom lays lacustrine chalk containing more than 80% $CaCO_3$. This area is subjected to periodic waterlogging. The water level shows fluctuations of high amplitude. In the meadow areas agrotechnical intervention led to mixing and aeration of the soil layers on the object M1 with 19% of $CaCO_3$, but over 73% on M2. The location of the meadows in the immediate vicinity of the Giławka river causes waterlogged soils, which are sometimes flooded. The excess water is drained by a system of drainage ditches. A description of particular environmental variables in the studied areas are contained in table 1. At the study sites soil samples were taken and standard methods for identification of soil characteristics were carried out (Lemkowska, Sowiński 2008). The following properties were determined: soil pH in distilled water and 1 M KCl, potentiometrically; calcium carbonate ($CaCO_3$) content by the volumetric Scheibler method. Undisturbed soil samples were collected in stainless steel rings (100 cm^3) for determination of bulk density and water properties. The soil water content was determined after drying the cylinder samples at 105°C.

Carabid sampling

In 2013, ground beetles were pitfall-trapped using modified Barber traps, which were 400 ml plastic cups filled with ca. 130 ml ethylene glycol as a preservative medium. The traps were dug into the ground so that the upper edge was level with the soil surface. On each of the studied four sites, six Barber traps were set in a line about 10 meters from one another. The traps were exposed from May to the end of October and emptied every fortnight.

Data analysis

The collected material was identified to the species using the key by Hůrka (1996) and nomenclature by Aleksandrowicz (2004). Carabid beetles were analysed in terms of their species composition, abundance, richness and some life-history traits such as habitat, trophic, moisture preferences as well as type of breeding. In order to elaborate the ecological characteristics of Carabidae we referred to the following papers: Larsson 1939; Sharova 1974; Thiele 1977; Lindroth 1985, 1986; Aleksandrowicz 2004; Brandmayr et al. 2005. The following indices were used for determining the diversity of the Carabidae assemblages: Shannon-Weaver's species diversity (H', log base 2,718), Pielou's species evenness (J'), and Simpson's species richness (D). The expected species number in the objects was estimated using the Jackknife estimation technique of species richness (Zahl 1977). The randomization of samples was achieved using EstimateS v. 9.1.0 (Colwell 2005). Indirect ordination of carabid beetle assemblages found at the study area was performed using non-metric multidimensional scaling (NMDS). The NMDS was calculated in WinKyst 1.0

(Šmilauer, 2002) on a Bray-Curtis similarity matrix, based on an initial configuration generated by principal coordinate analysis. The distribution of the data was tested for normality using the Shapiro-Wilk test. The differences between the mean values of the abundance of individuals and number of species and in particular life-traits total abundance between the study sites were tested by means of a Poisson generalized linear model (GLM). Tests for the significance of the effects in the model were performed by means of the Wald statistic. Connections between the Carabidae species and habitat-related conditions (humidity, height above sea level, management of the area: mowing, neighborhood: forest, arable fields) were assessed with the redundancy analysis (RDA). The RDA method was chosen following an analysis of the data distribution, which proved to be linear (at a DCA-gradient length of 2.33). The statistical significance of the canonical axes was determined according to the Monte Carlo test. Statistical calculations and their graphic interpretation were performed with the software packages Statistica 11.0 PL and Canoco 4.5 (ter Braak & Šmilauer 1998).

RESULTS

In total, 1,573 individuals of carabid beetles representing 39 species were captured (tab. 2). On the unmanaged wetlands, the dominant species was *Dyschirius globosus* – a small hygrophilic zoophagous species – and meadows bordering arable fields were dominated by the large species *Carabus granulatus*. The Shannon Diversity value ranged from 2.16 on the meadows to 1.69 on the unused wetland. Similarly, associated with the rate of Shannon Diversity, the Pielou evenness index reached higher values in the meadows (0.699 and 0.674) than in the non-cultivated wetlands (0.605 and 0.563). The Simpson diversity indices calculated for the studied objects were relatively high (0.20–0.36). Significant differences ($F = 7.39$; $p < 0.01$) were observed between the examined sites with respect to the number of captured individuals (fig. 1), with a significant higher number of individuals on wetland 1 compared to the other study sites. This study site is the least wet among the studied objects. The rarefaction analysis showed that the expected number of species in the wetlands (W1, W2) was placed between twenty-five and thirty-two species (fig. 2). At the meadows (M1, M2) the values were almost the same. The curves on the diagrams are almost parallel to the x-axis, which indicates that the expected numbers of species were caught. However, no statistical significant differences appeared between the sites in terms of the number of species (fig. 1). Nonetheless, the examined meadows and wetlands were considerably

Table 1. Description of selected environmental variables in the studied sites

Environment variable	Studied sites			
	W 1	W 2	M 1	M 2
Humidity % weight	62.9	73.3	87.9	79.2
HASL - height above see level (m)	110	109	105	105
Mowing	lack	lack	once a year 10 VI 2013	once a year 10 VI 2013
Fields (distance in m)	lack of nearby	lack of nearby	50	200
Forest (distance in m)	100	150	lack of nearby	lack of nearby

Table 2. Number of species and individuals of Carabidae caught in the studied sites

Species	Abbreviatior	Studied sites							
		Wetland_1		Wetland_2		Meadow_1		Meadow_2	
		n	%	n	%	n	%	n	%
Agonum viduum (Panzer,1797)	Ag_vid					30	9.65	4	1.30
Amara communis (Panzer,1797)	A_com	8	1.37	3	0.81				
Anisodactylus binotatus (Fabricius,1787)	An_bin					1	0.32		
Badister bullatus (Schrank,1798)	Ba_bull							1	0.33
B. sodalis (Duftschmid,1812)	Ba_sod	7	1.19	2	0.54	1	0.32		
Bembidion biguttatum (Fabricius,1779)	B_bigut					10	3.22	5	1.63
B. gilvipes (Sturm,1825)	B_gilv	21	3.58	9	2.44			2	0.65
B. guttula (Fabricius,1792)	B_gutt	2	0.34	1	0.27	12	3.86	21	6.84
B. lampros (Herbst, 1784)	B_lam							1	0.33
B. mannerheimii (C.Sahlberg,1827)	B_mann	20	3.41	25	6.78	7	2.25	3	0.98
B. properans (Stephens,1828)	B_prop					1	0.32		
Blemus discus (Fabricius,1792)	Bl_disc	4	0.68	1	0.27				
Blethisa multipunctata (Linnaeus,1758)	Bl_multip					1	0.32		
Carabus granulatus Linnaeus,1758	C_gran	36	6.14	25	6.78	127	40.84	143	46.58
C. marginalis Fabricius,1794	C_marg	1	0.17						
Chlaenius nigricornis (Fabricius,1787)	Ch_nigri					9	2.89	8	2.61
Clivina fossor (Linnaeus,1758)	Cli_foss	5	0.85	1	0.27			1	0.33
Curtonotus aulicus (Panzer,1797)	Cu_aulic	3	0.51						
Cychrus caraboides (Linnaeus,1758)	Cy_carab	1	0.17						
Dyschirius globosus (Herbst,1784)	D_glob	243	41.47	216	58.54	16	5.14	20	6.51
Epaphius rivularis (Gyllenhal,1810)	E_rivul			4	1.08				
E. secalis (Paykull,1790)	E_seca	152	25.94	27	7.32			9	2.93
Europhilus fuliginosus (Panzer,1809)	Eu_fulig	1	0.17			3	0.96	5	1.63
Harpalus rufipes (De Geer,1774)	H_rufip	1	0.17	2	0.54			1	0.33
Loricera pilicornis (Fabricius,1775)	L_pilic					1	0.32		
Oodes helopioides (Fabricius,1792)	O_helop					13	4.18	9	2.93
Poecilus cupreus (Linnaeus,1758)	Po_cup	1	0.17					1	0.33
P. versicolor (Sturm,1824)	Po_vers	6	1.02	2	0.54	5	1.61	15	4.89
Pterostichus aethiops (Panzer,1797)	P_aeth					1	0.32		
P. diligens (Sturm,1824)	P_dilig	7	1.19	14	3.79	4	1.29	6	1.95
P. melanarius (Illiger,1798)	P_melan	19	3.24	13	3.52	2	0.64		
P. niger (Schaller,1783)	P_nig	26	4.44	10	2.71	11	3.54	3	0.98
P. nigrita (Paykull, 1790)	P_nigri					41	13.18	28	9.12
P. oblongopunctatus (Fabricius, 1787)	P_obl	2	0.34						
P. rhaeticus Heer,1838	P_rhae					2	0.64		
P. strenuus (Panzer,1797)	P_stren	4	0.68	4	1.08				
P. vernalis (Panzer,1796)	P_vern	12	2.05	8	2.17	13	4.18	21	6.84
Stomis pumicatus (Panzer,1796)	St_pumi	4	0.68	1	0.27				
Trechus quadristriatus (Schrank,1781)	T_quadri			1	0.27				
Number of individuals		586	100.00	369	100.00	311	100.00	307	100.00
Number of species		24		20		22		21	
Shannon-Weaver diversity H' (Log base 2.718)		1.924		1.685		2.162		2.053	
Pielou evenness J		0.605		0.563		0.699		0.674	
Simpson diversity D		0.248		0.36		0.203		0.243	

different in the species composition of the captured specimens of ground beetles (tab. 2). This is shown in the non-metric multidimensional scaling diagram (NMDS). The unmanaged wetlands and meadows assemblages are separated (fig. 3). The meadows assemblages are closer to each other than the wetland ones.

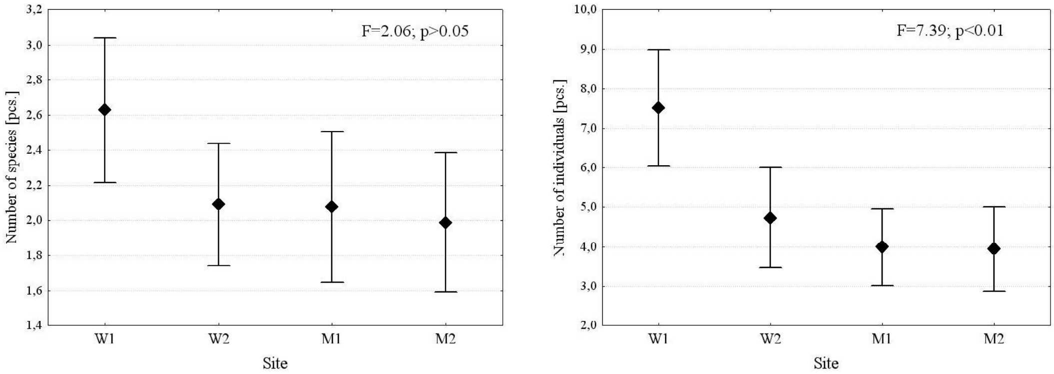

Fig. 1. Number of species (right) and individuals (left) caught in the studied sites (W1, W2, M1, M2 - study sites described in Materials and Methods; a,b - means indicated by the same letter do not differ - Tukey's test HSD)

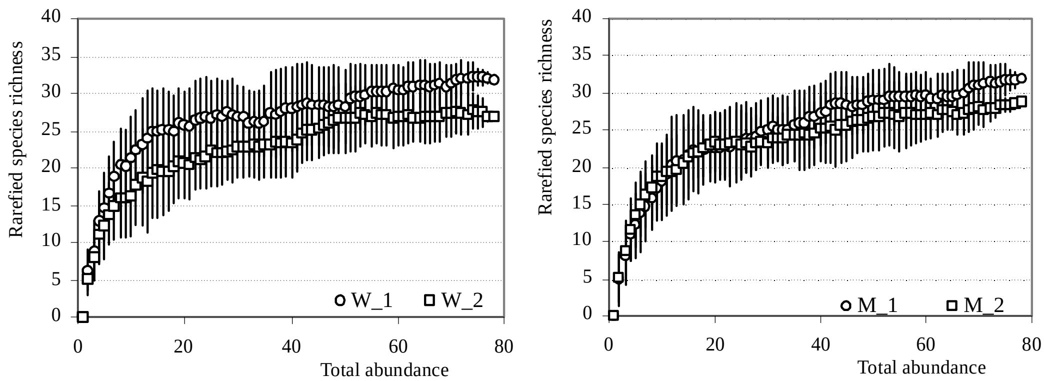

Fig. 2. Expected number of carabid species caught in the studied sites using the Jackknife estimator (± SD) of species richness (W1, W2, M1, M2 – study sites described in Material and Methods)

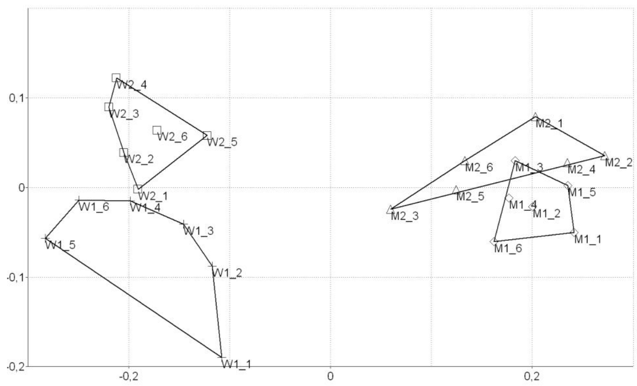

Fig. 3. Diagram of non-metric multidimensional scaling (NMDS) performed on Bray-Curtis similarity matrix of the studied ground beetle assemblages (W1, W2, M1, M2 – study sites described in Material and Methods, with trap number attached)

Analysing the various life traits of ground beetles in the studied objects we noticed significant statistical differences (tab. 3). In wetter habitats (M1, M2) the abundance of carabid species preferring peat bog was higher than in the less wet sites (W1, W2) (fig. 4a). The situation is similar regarding the hygro-preferences of the carabid beetles (fig. 4b). Only hygrophilic species increased in abundance in the meadows (M1, M2). Regarding the trophic structure, we noticed that wet meadows (M1, M2) are not beneficial sites for small zoophages (fig. 4c). The proportion of the other trophic groups increased in the wet meadows (M1, M2). Analysing the breeding types of ground beetles, most numerous were spring breeders on both site types. The abundance of autumn breeders decreased in the wet meadows (M1, M2), (fig. 4d). The redundancy analysis diagram revealed that the presence of forest correlates to the first ordination axis ($F = 25.96$; $p = 0.002$), which describes over 90% of the variability. Other important environmental factors are height above sea level and agricultural practices, such as mowing.

DISCUSSION

When comparing the collected material to research on Carabidae in wetlands by other authors from Poland (Huruk 2003, 2006; Sienkiewicz 2003; Huruk & Huruk 2004), our study sites were not very rich both from the point of view of the number of the specimens caught and the species. The Shannon Diversity index was lower then shown by other authors for wet grassland sites (Nietupski et al. 2007; Huruk 2006). The analysis of the species composition of Carabidae of the investigated sites shows that despite having the same type of soil, the assemblages differed widely. Consequently, the conclusion can be drawn that the type of soil is not a factor that determines the composition of the Carabidae assemblages. Numerous authors (Thiele 1977; Blake et al.

Table 3. GLM of the effects of type of calcareous gyttja soil on abundance and species richness of carabids assemblages

Ecological traits	df	Wald Stat.	p
Habitat preferences			
Peat bog	3	29.47	p<0.01
Open area	3	205.57	p<0.01
Eurytopic	3	195.01	p<0.01
Forest	3	29.57	p<0.01
Hygropreferences			
Hygrophilic	3	68.25	p<0.01
Mesohygrophilic	3	75.76	p<0.01
Mesophilic	3	248.00	p<0.01
Mesoxerophilic	3	0.00	p>0.05
Trophic preferences			
Hemizoophages	3	11.58	p<0.01
Small zoophages	3	382.14	p<0.01
Medium zoophages	3	82.91	p<0.01
Large zoophages	3	10.38	p<0.05
Type of breeding			
Spring breeders	3	13.70	p<0.01
Autumn breeders	3	222.86	p<0.01

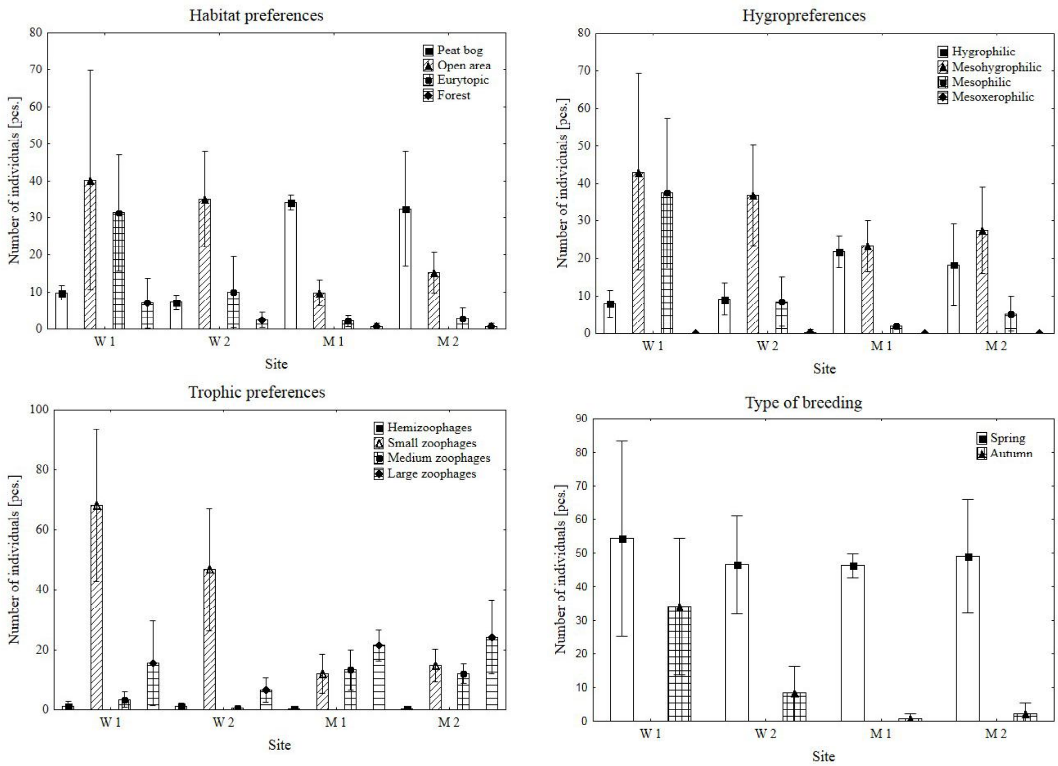

Fig. 4. Average abundance of carabids belonging to different ecological groups recorded in the studied sites (W1, W2, M1, M2 – study sites described in Material and Methods; vertical lines with average mean SE)

1994; Bettacchioli et al. 2012; Lafage & Pétillon 2014; Skłodowski 2014b; Williams et al. 2014) draw special attention to factors influencing the formation of Carabidae assemblages such as moisture of the habitat, the composition of the flora, usage of the grassland and the nearest neighborhood. In the conducted study, considerable differences were noticed between the species composition of Carabidae of the investigated habitats. The Carabidae caught on mown meadows were similar to meadow assemblages described by other authors (Sienkiewicz 2003; Huruk & Huruk 2004; Gerisch et al. 2006; Nietupski et al. 2007). On sites W1, W2, not under agricultural use, the species composition of Carabidae resembled more the assemblages described for peatbogs (Alekandrowicz 2002; Hollmen et al. 2008; Nietupski et al. 2008; Jaskuła & Stępień 2012). This indicates the strong impact of the manner of use of the sites under research. In grassland left without human management we noticed completely different assemblages of Carabidae. However, Sienkiewicz (2003), does not share the opinion that increasing human intervention reduces the share of large and medium zoophages for the benefit of hemizoophages and small zoophages. In research on unmanaged wetlands, the majority of the assembly was composed of Carabidae, such as *Dyschirius globosus*, *Epaphius secalis*, *Bembidion gilvipes* and *Bembidion mannerheimii*. Maybe, those Carabidae, due to their small size and increased mobility, select characteristic micro-habitats on objects that are not subject to any agro-technical procedures and which are covered with high plants where large and medium sized, less mobile zoophages occur reluctantly. The larger carabids more frequently selected the easier to penetrate mown grasslands. Mortimer et al. (1998) indicated that the insect fauna of lowland calcareous grassland depends on the structure and composition of the vegetation and the effects of topography and vegetation on microclimatic conditions.

Moisture is known as one of the most important factors influencing carabid beetle assemblages (Thiele 1977; Bettacchioli et al. 2012; Skłodowski 2014b). While analyzing the number of carabids belonging to particular habitat groups, the strong influence of moisture of the habitat was noticed which reduced the number of carabids of the majority of the habitat groups. Only carabid species inhabiting peatbog, which prefer wetlands, indicated a tendency to increase in number towards wet carbonate grasslands. Those grasslands were located at the bottom of the former lake; consequently, the moisture of the soil was always very high there.

With respect to phenological analysis of the beetles caught we mostly observed spring breeders on both types of sites. The abundance of autumn breeders decreased in wet meadows. It is probable that wet soils do not create favourable environmental conditions for the long-living larval stages of autumn breeding Carabidae. Thiele (1977) and Gerisch (2011) indicated that early reproduction, by avoiding spring and autumn hydrological disturbances, is a crucial strategy to reach reproductive success in so highly dynamic habitats.

Wet meadows and unused wetlands located on a calcareous gyttja soil are specific places where we can find some interesting species. For example, *Blemus discus* is a rare species, specific to alkaline soils, and *Blethisa multipunctata* is a rather rare species in Poland connected to flooded and very wet areas.

CONCLUSIONS

The factors that most probably differentiated the species composition of Carabid beetles on calcareous grasslands were different land use, changeable moisture conditions and the presence of forests in the surrounding of the habitats.

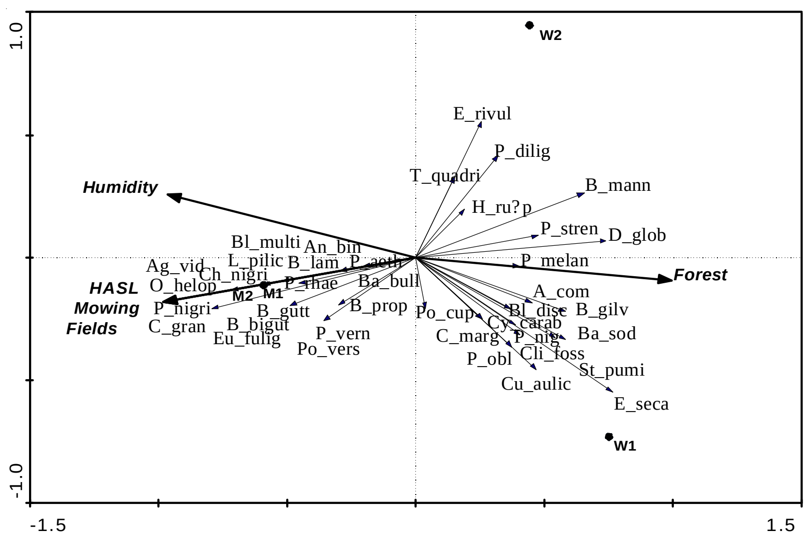

Fig. 5. Diagram of the RDA analysis demonstrating the relationships between the analyzed environmental variables and Carabidae species in the studied sites (W1, W2, M1, M2 – study sites described in Material and Methods, with trap number attached; HASL - height above sea level; Humidity - the soil water content of each studied sites; Mowing – the presence or lack of mowing; Fields - distance to crop fields; Forest - distance to forest; for abbreviations of carabid species see tab. 2)

Grasslands located on carbonate soils, especially those excluded from agricultural use, are a habitat that harbor precious and rare Carabidae fauna, and they should be subject to close monitoring.

REFERENCES

Aleksandrowicz O.R. 2002. Changes in the carabid fauna of Polesie peat-bog due to drainage, ploughing and agricultural development. In: Szyszko et al. (eds). How to protect or what we know about Carabid Beetles. Warsaw Agricultural University Press: 171–184.

Aleksandrowicz O.R. 2004. Biegaczowate (Carabidae). (Ground beetles (Carabidae)) In: Bogdanowicz W., Chudziaka E., Pilipiuk I., Skibińska E. (eds.). Fauna Polski □ —“H—“□ charakterystyka i wykaz gatunków. (Polish Fauna - the characteristics and the list of species). Muzeum i Instytut Zoologii PAN. Warszawa I: 28–42. (In Polish).

Andersen J. 2011. Winter quarters of wetland ground beetles (Coleoptera, Carabidae) in South Scandinavia. Journal of Insect Conservation 15: 799–810.

Arend E. 1894. Masurische Moorwiesen und deren Ertraege. Königsberg. 62: 398–408.

Bartkowiak S.A., Długosz J., 2011. Właściwości gleby występującej na martwicy wapiennej w Basenie Unisławskim. W: Wybrane problemy genezy, systematyki, użytkowania i ochrony gleb regionu kujawsko-pomorskiego (Soil properties occurring on calcareous tufa in the Unislawski Basin). In: Jankowski M. (eds.) Wybrane problemy genezy, systematyki, użytkowania i ochrony gleb regionu kujawsko-pomorskiego (Selected problems of genesis, systematics, use and protection of soils of Kujawsko-Pomorskie region). PTSH Wrocław, PTG Warszawa: 65–77.

Bettacchioli G., Taormina M., Bernini F., Migliorini M. 2012. Disturbance regimes in a wetland remnant: implications for trait-displacements and shifts in the assemblage structure of carabid beetles (Coleoptera: Carabidae). Journal of Insect Conservation 16: 249–261.

Blake S., Foster G.N., Eyre M.D., Luff M.L. 1994. Effects of habitat type and grassland management practices on the body size distribution of carabid beetles. Pedobiologia 38: 502–512.

Brandmayr P., Zetto T., Pizzolotto R. 2005. I coleotteri carabidi per la valutazione ambientale e la conservazione della biodiversità. Manuale operativo. APAT – Agenzia nazionale per la protezione dell'ambiente e per i servizi tecnici, Roma, via Vitaliano Brancati, 48. Manuali e linee guida 34: 240 pp.

Cole L.J., Pollock M.L., Robertson D., Holland J.P., McCracken D.I., Harrison W. 2010. The influence of fine-scale habitat heterogeneity on invertebrate assemblage structure in upland semi-natural grassland. Agriculture, Ecosystems and Environment 136: 69–80.

Colwell R.K. 2005-. EstimateS, Statistical estimation of species richness and shared species from samples, ver 9.1.0.- User's Guide and application available at: http://purl.oclc.org/estimates.

Czechowski W. 1989. Carabid Beetles (Coleoptera, Carabidae) of Moist Meadows on the Mazovian Lowland. Memorabilia Zoologica 43: 141–167.

Do Y., Jo H., Kang J.-H., Joo G.-J. 2012. Spatial-temporal distribution of carabid beetles in wetlands. Journal of Ecology and Field Biology 35: 51–58.

Gerisch M., Schanowski A., Figura W., Gerken B., Dziock F., Henle K. 2006. Carabid Beetles (Coleoptera, Carabidae) as Indicators of Hydrological Site Conditions in Floodplain Grassland. International Review of Hydrobiology 91: 326–340.

Gerisch M. 2011. Habitat disturbance and hydrological parameters determine the body size and reproductive strategy of alluvial ground beetles. Zookeys 100: 353–370.

Grandchamp A-C., Bergamini A., Stofer S., Niemelä J., Duelli P., Scheidegger C. 2005. The influence of grassland management on ground beetles (Carabidae, Coleoptera) in Swiss montane meadows. Agriculture, Ecosystems and Environment 110: 307–317.

Hăjek D., Horsak M., Hăjkovă P., Ditě D. 2006. Habitat diversity of central European fens in relation to environmental gradients and an effort to standardise fen terminology in ecological studies. Perspectives in Plant Ecology. Evolution and Systematics 8: 97–114.

Hollmen A., Välimäki P., Itämies J., Oksanen J. 2008. The value of open power line habitat in conservation of ground beetles (Coleoptera: Carabidae) associated with mires. Journal of Insect Conservation 12: 163–177.

Huruk S. 2003.Ground beetles (Coleoptera: Carabidae) of moist hay meadows along the Nida River near Korytnica (Central Poland). Baltic Journal of Coleopterology 3: 145–151.

Huruk S. 2006. Porównanie struktur zgrupowań biegaczowatych (Coleoptera: Carabidae) łąk kośnych oraz przylegających do nich pól uprawnych (Comparison of structure of carabid (Coleoptera: Carabidae) communities of hay meadows and adjacent cultivated fields). Wiadomości Entomologiczne 25: 9–32 (In Polish; abstract in English).

Huruk S., Huruk A. 2004. Ground beetles (Coleoptera: Carabidae) of moist hay meadows along the River San near the town of Rudnik in Central Poland. Baltic Journal of Coleopterology 4: 23–29.

Hůrka K. 1996. Carabidae of the Czech and Slovak Republics. Kabournek, Zlin, CZ, 565 pp.

Jaskuła R., Stępień A. 2012. Ground beetle fauna (Coleoptera: Carabidae) of protected areas in the Łódź Province. Part I. Nature reserves. Fragmenta Faunistica 55: 101–122.

Koivula, M. J. 2011. Useful model organisms, indicators, or both? Ground beetles (Coleoptera, Carabidae) reflecting environmental conditions. In: Kotze D.J., Assmann T., Noordijk J., Turin H., Vermeulen R. (eds.). Carabid beetles as bioindicators: biogeographical, ecological and environmental studies. ZooKeys 100: 287–317.

Kotze J.D., Brandmayr, P., Casale, A., Dauffy-Richard E., Dekoninck W., Koivula M.J., Lövei G.L., Mossakowski D., Noordijk J., Paarmann W., Pizzolotto R., Saska P., Schwerk A., Serrano J., Szyszko J., Taboada A., Turin H., Venn S., Vermeulen R., Zetto T. 2011. Forty years of carabid beetle research in Europe - from taxonomy, biology, ecology and population studies to bioindication, habitat assessment and conservation. Zookeys 100: 55–148.

Kuźnicki F. 1976. Rędziny wytworzone ze skał węglanowych różnych formacji geologicznych na obszarze Gór Świętokrzyskich i ich obrzeżenia. (Rendzina soils developed from carbonate rocks of different geological formations over the area of the Świętokrzyskie Mountains and their borderings). Roczniki Gleboznawcze 27: 19–48. (In Polish; abstract in English).

Lafage D., Pétillon J. 2014. Impact of cutting date on carabids and spiders in a wet meadow. Agriculture, Ecosystems and Environment 185: 1–8.

Lambeets K., Vandegehuchte M.L., Maelfait J-P., Bonte D. 2008. Understanding the impact of flooding on trait-displacements and shifts in assemblage structure of predatory arthropods on river banks. Journal of Animal Ecology 77: 1162–1174.

Larsson S.G. 1939. Entwicklungstypen und Entwicklungszeiten der dän. Carabiden. Entomologiske Meddelelser 20: 277–560.

Lemkowska B., Sowiñski P. 2008. Ewolucja „rêdzin pojeziornych" w krajobrazie Pojezierza Mazurskiego (Evolution of „post-lake rendzinas" in the landscape of the Mazurian Lakeland). Roczniki Gleboznawcze. 59: 134–140. (In Polish; abstract in English).

Lik M. 2010. The influence of habitat type on the population dynamics of ground beetles (Coleoptera: Carabidae) in marshland. Annales de la Societe Entomologique de France 46: 425–438.

Lindroth C.H. 1985. The Carabidae (Coleoptera) of Fennoscandia and Denmark. Fauna Entomologica Scandinavica 15: 1–225.

Lindroth C.H. 1986. The Carabidae (Coleoptera) of Fennoscandia and Denmark. Fauna Entomologica Scandinavica 15: 230–497.

Maltby E., Barker T. 2009. The Wetlands Handbook. Wiley-Blackwell: 800 pp.

Meller E. 2006. Płytkie gleby organogeniczno-węglanowe na kredzie jeziornej i ich przeobrażenia w wyniku uprawy (Shallow organogenic-calcareous soils on lacustrine chalk and their transformation resulted from cultivation). AR Szczecin. Rozprawy 233. (In Polish; abstract in English).

Meller E., Sienkiewicz M., Niedźwiecki E., Gołębiewska D., 2009. Parametry związków próchnicznych gleb pobagiennych wytworzonych na kredzie jeziornej jako wskaźniki ich przynależności systematycznej. (Parameters of humic compounds of post-bog soils developed on calcareous chalk as identification criteria of their taxonomy). Roczniki Gleboznawcze 60: 114–122 (In Polish; abstract in English).

Mitsch W.J., Gosselink J.G., Anderson C.J., Zhang L. 2009. Wetland Ecosystems, John Wiley & Sons, Inc., New York. 295 pp.

Moran J., Gormally M.J., Skeffington S. 2012. Turlough ground beetle communities: the influence of hydrology and grazing in a complex ecological matrix. Journal of Insect Conservation 16: 51–69.

Mortimer S.R., Hollier J.A., Brown V.K. 1998. Interactions between plant and insect diversity in the restoration of lowland calcareous grasslands in southern Britain. Applied Vegetation Science 1: 101–114.

Mortimer S.R., Booth R.G., Harris S.J., Brown V.K. 2002. Effects of initial site management on the Coleoptera assemblages colonising newly established chalk grassland on ex-arable land. Biological Conservation 104: 301–313.

Mückenhausen E. 1962. Entstehung, Eigenschaften und Systematik der Böden der Bundesrepublik Deutschland, DLG-Verlag, Frankfurt, 1 Auflage: 148 pp.

Nietupski M., Kosewska A., Ciepielewska D., 2007. Zgrupowania epigeicznych biegaczowatych (Coleoptera: Carabidae) dwóch śródleśnych łąk kośnych o różnym stopniu uwilgotnienia, w okolicach Olsztyna (Assemblages of epigeic carabids (Coleoptera: Carabidae) in two cut meadows located in a forest with different moisture content in the soil, in the Olsztyn vicinity). Wiadomości Entomologiczne 26: 185–193. (In Polish; abstract in English).

Nietupski M., Ciepielewska D., Kosewska A. 2008. Assemblages of epigeic Carabidae (Col.) in a peatbog nature reserve situated in an urban area. Polish Journal of Natural Science 23: 611–623.

Ödman A.M., Mårtensson L-M., Sjöholm C., Olsson P.A. 2011. Immediate responses in soil chemistry, vegetation and ground beetles to soil perturbation when implemented as a restoration measure in decalcified sandy grassland. Biodiversity and Conservation 20: 3039–3058.

Piaścik H., Lemkowska B. 2004. Genese der Niedermoore in der Masurischen Seeplatte. Telma 34: 31–37.

Pietzsch D., Ochsner S., Mantilla-Contreras J., Hampicke U. 2013. Low-intensity Husbandry as a Cost-efficient Way to Preserve Dry Grasslands. Landscape Research 38: 523–539.

Porhajašová J., Šustek Z., Noskovič J., Urminská J., Ondrišík P. 2010. Spatial changes and succession of carabid communities (Coleoptera, Insecta) in seminatural wetland habitats of the Žitava river floodplain. Folia Oecologica 37: 75–85.

Rainio J., Niemelä J. 2003. Ground beetles (Coleoptera: Carabidae) as bioindicators. Biodiversity and Conservation 12: 487–506.

Ruta R. 2013. Murawy nakredowe nad jeziorami Załom i Dypa koło Człopy historia badań, użytkowania i ochrony. (Lake marl grasslands by Załom and Dypa lakes near Człopa – history of research, management and protection). Przegląd Przyrodniczy 24: 19–55. (In Polish; abstract in English).

Schirmel J., Alt M., Rudolph I., Entling M.H. 2014. Effects of traditional flood irrigation on invertebrates in lowland meadows. PLoS ONE 9 (10) article number e110854.

Schirmel J., Mantilla-Contrerasb J., Gauger D., Blindow I. 2015. Carabid beetles as indicators for shrub encroachment in dry grasslands. Ecological Indicators 49: 76–82.

Schwerk A. Szyszko J. 2011: Model of succession in degraded areas based on carabid beetles (Coleoptera, Carabidae). ZooKeys 100: 319–332.

Sharova I. H. 1974. Zhiznennye formy imago zhuzhelits (Coleoptera, Carabidae). Zoologichesky Zhurnal 53: 692–709. (In Russian).

Sienkiewicz P. 2003. Ground beetles (Coleoptera: Carabidae) of the seasonally flooded meadows in the valley of the middle course of the Warta – qualitative analysis. Baltic Journal of Coleopterology 3: 129–136.

Sienkiewicz P., Zmihorski M. 2012. The effect of disturbance caused by rivers flooding on ground beetles Coleoptera: Carabidae. European Journal of Entomology 109: 535–541.

Skalski T., Kędzior R., Radecki-Pawlik A. 2012. Riverine ground beetles as indicators of inundation frequency of mountain stream: a case study of the Ochotnica Stream, Southern Poland. Baltic Journal of Coleopterology 12: 117–126.

Skłodowski J. 2014a. Effects of top-soil preparation and broad-leaved tree mixture on carabid beetles in afforested fallow plots. Restoration Ecology 22: 13–21.

Skłodowski J. 2014b. Consequence of the transformation of a primeval forest into a managed forest for carabid beetles (Coleoptera: Carabidae) - a case study from Białowieża (Poland). European Journal of Entomology 111: 639–648.

Šmilauer P. 2002: WinKyst 1.0, Ceske Budejovice, Czech Republic.

ter Braak C.J.F., Šmilauer P. 1998: CANOCO Reference Manual and User's Guide to Canoco for Windows. Microcomputer Power, Ithaca, USA, 352 pp.

Thiele H.U. 1977: Carabid beetles in their environments. Springer-Verlag, 329 pp.

Uggla H. 1976. Rędziny Pojezierza Mazurskiego. (Rendzinas in the Mazurian Lakeland). Roczniki Gleboznawcze 27: 113–125. (In Polish; abstract in English).

Venn S.J., Kotze J., Lassila T., Niemela J. 2013. Urban dry meadows provide valuable habitat for granivorous and xerophylic carabid beetles. Journal of Insect Conservation 17: 747–764.

Wamser S., Diekötter T., Boldt L., Wolters V. & Dauber J. 2012: Trait-specific effects of habitat isolation on carabid species richness and community composition in managed grasslands. Insect Conservation and Diversity 5: 9–18.

Williams C.D., Hayes M., Mc Donnell R.J., Anderson R., Bleasdale A., Gormally M.J. 2014. Factors affecting wetland ground beetle (Carabidae) assemblages: how important are habitats, conservation designations and management? Insect Conservation and Diversity 7: 206–222.

World Reference Base for Soil Resources. 2006. A framework for international classification, correlation and communication. FAO-ISRIC-ISSS. World Soil Resources Report, Rome:103: 145 pp.

Zahl S., 1977.- Jackkning an index of diversity.- Ecology, 58: 907–913.

Zulka K. P. 1994. Carabids in a Central European floodplain: species distribution and survival during inundations, p. 399–405. in: Desender K., Dufrêne M., Loreau M., Luff M. L., Maelfait J.-P. (eds.), Carabid beetles, Ecology and Evolution. Kluwer Academic Publishers, Dordrecht.

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