J. Elementol. 2010, 15(3): 581–591

CONTENT OF ORGANIC C AND pH OF BOG AND POST-BOG SOILS VERSUS THE PRESENCE OF GROUND BEETLES *CARABIDAE* IN STARY DWÓR NEAR OLSZTYN

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Abstract

The present study consisted of an evaluation of assemblages of epigeic carabid beetles (*Col. Carabidae*) colonizing hydrogenic soils (bog and post-bog ones), different in the soil development degree. The observations were conducted on a drained, low bog area called Stary Dwór, which today is used as a cut meadow. This is an oblong depression, filled in with (partly mucky) rush peats and situated in the sandur landscape. It lies in the mesoregion called Pojezierze Olsztyńskie (Olsztyn Lake District) near Olsztyn (UTM DE 65), about 3 km of the southern borders of the town. The field observations for determination of the soil type were conducted using soil catenas. A transect was established, which cut across different types and sub-types of bog and post-bog soils. In this paper, the authors have attempted to answer the question whether the sequence of hydrogenic soils and some parameters chosen to describe them have any influence on assemblages of epigeic carabid beetles dwelling in such habitats. Based on the results, it has been concluded that the soils present in the analyzed peat bog were characterized by the following sequence: muckous soils → peat-muck soils → peat soils. Their properties depended on the position in the soil relief, advancement of muck formation and content of organic carbon. It has been found out that the highest soil ash content in the surface horizons was in muckous soil (90.39%), and the lowest – in profile 3 of peat-muck soil (18.77%). The reaction of the analyzed soils ranged from slightly acidic to neutral and tended to decrease towards the centre of the depression, reaching the lowest value in peat soil. During the two years of our observations, a total of 673 individuals of *Carabidae* belonging to 29 species were captured. It has

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been determined that the type of soil as a factor significantly affected the number of captured carabid beetles, but did not influence the species abundance. The decreasing pH gradient as well as an increasing content of organic C were associated with a decreasing number of the species of carabid beeetles tolerant to moisture conditions (mesophilous species), which were being replaced by hygrophilous individuals. As the acidic reaction of soil increased and the soil content of organic matter rose, so did the abundance of mixophagous species at the expense of predatory individuals.

Key words: organic C, soil pH, *Carabidae*, bog soils, post-bog soils.

ZAWARTOŚĆ C ORGANICZNEGO I pH GLEB BAGIENNYCH I POBAGIENNYCH A WYSTĘPOWANIE NAZIEMNYCH *CARABIDAE* W OBIEKCIE STARY DWÓR k. OLSZTYNA

Abstrakt

W badaniach poddano ocenie zgrupowania epigeicznych biegaczowatych (*Col.*, *Carabidae*) zasiedlających gleby hydrogeniczne (bagienne i pobagienne) o różnym stopniu rozwoju. Terenem badań było odwodnione torfowisko niskie Stary Dwór, użytkowane jako łąka kośna. Obiekt stanowi podłużne zagłębienie wypełnione torfami szuwarowymi (częściowo zmurszałymi) w krajobrazie sandrowym. Jest on zlokalizowany w mezoregionie Pojezierza Olsztyńskiego, w pobliżu Olsztyna (UTM DE 65), w odległości ok. 3 km od południowych granic miasta. Prace terenowe, w których określano typ gleby, prowadzono metodą katen glebowych. Wyznaczono transekt przebiegający przez różne typy i podtypy gleb bagiennych i pobagiennych. W pracy próbowano uzyskać odpowiedź na pytanie, czy sekwencja gleb hydrogenicznych oraz wybrane parametry opisujące te gleby mają wpływ na zgrupowania zasiedlających je epigeicznych biegaczowatych. Stwierdzono, że opisane na badanym torfowisku gleby charakteryzowały się następującą sekwencją: gleby murszaste → gleby torfowo-murszowe → gleby torfowe. Ich właściwości były uzależnione od usytuowania w reliefie, zaawansowania procesu murszenia oraz zawartości C organicznego. Największą popielność stwierdzono w poziomach powierzchniowych gleby murszastej (90,39%), natomiast najniższą w profilu 3 (18,77%) gleby torfowo-murszowej. Odczyn badanych gleb kształtował się od lekko kwaśnego do obojętnego i malał w kierunku centrum obniżenia, osiągając najniższe wartości w glebie torfowej. W czasie dwuletnich obserwacji na badanym obiekcie odłowiono łącznie 673 osobniki *Carabidae* należące do 29 gatunków. Stwierdzono, że typ gleby okazał się czynnikiem istotnie wpływającym na liczbę odłowionych osobników *Carabidae*, natomiast nie wpływał na ich bogactwo gatunkowe. Malejący gradient pH oraz wzrastająca zawartość C organicznego wiązały się ze spadkiem liczebności osobników badanej grupy chrząszczy, mało wrażliwych na zmieniające się warunki wilgotnościowe (mezofile), i zastępowaniem ich przez osobniki wilgociolubne. Wraz ze zwiększającą się kwasowością gleby i zawartością materii organicznej wzrastała również liczebność miksofagów, kosztem zmniejszania się grupy osobników drapieżnych.

Słowa kluczowe: C organiczny, pH gleby, *Carabidae*, gleby bagienne, gleby pobagienne.

INTRODUCTION

Soil properties are of an immense importance for the shaping of components of agrocenoses, and especially populations of arthropods dwelling in soil habitats. Among arthropods, carabid beetles are a very important and valuable group of animals, very strongly connected with the soil environment. These beetles are mostly predators, hence they can limit gradation of phytophagous animals; besides, they are commonly used for zoological indication (RAINIO, NIEMELA 2003). Soil properties are characterized by a number of physical and chemical parameters, which also affect *Carabidae*. Some of the more important chemical properties of soil are soil reaction (pH), soil salinity and soil content of calcium carbonate. Other important properties of soil are the particle size distribution and soil content of organic matter. These factors have a large influence on soil microclimate, including soil moisture and temperature. The vertical gradient of changes in these parameters affects migration of soil invertebrates and modifications in quantitative ratios between trophic groups of these organisms (BEZKOROVAINAYA, YASHIKHIN 2003). SĄDEJ et al. (2008) demonstrated a significant, positive effect of the content of organic C and positive effect of total nitrogen in lessive soil on the density of soil macrofauna.

This article deals with an assessment of epigeic carabid beetles dwelling on hydrogenic soils (bog and post-bog soils), different in the development degree. The properties of these soils in the surface horizon, for example specific and bulk density, total porosity and pH, differed as well. The authors hoped to answer the question whether the sequence of hydrogenic soils and the analyzed soil parameters had some influence on epigeic carabid beetles which colonized these soils.

THE RESEARCH AREA AND METHODS

The study was carried out on a drained, low bog area called Stary Dwór, now used as a cut meadow. This is an oblong depression filled in with (partly mucky) rush peats in the sandur landscape. It is situated in the mesoregion called Pojezierze Olsztyńskie (Olsztyn Lake District) near Olsztyn (UTM DE 65), about 3 km south of the town's borders. The field tests were carried out with the soil catena method. A transect was established that ran across different types and sub-types of bog and post-bog soils. The sequence of soils within the analyzed areas was as follows (from the edges towards the centre):
- muckous soils GM,
- peat-muck soils GMT1 and GMT2,
- peat soils GT.

The soil samples underwent the following determinations: ash content, bulk density, reaction and content of organic matter (C_{org}). The determinations were performed with the methods used in soil sciences for organic and mineral formations (SAPEK, SAPEK 1997). Longwise the established transect, four modified Barber traps were set up, one on each of the analyzed types of soil. They were filled with a fixing liquid and exposed from May to October in 2006 and 2007. The collected material was analyzed in terms of its species composition, dominance structure and zoogeography. In addition, the ecological characterization of the captured speciemens of *Carabidae* was drawn (THIELE 1977). The structure (classes) of dominance of the carabids was presented according to the following pattern: superdominants (>30%), eudominants (30-10%), dominants (10-5.1%), subdominants (5-2.1%), recedents (2-1.1%) and subrecedents (≥1%) (GÓRNY, GRÜM 1981). The siginifance of differences between the number of species and individuals captured on the analyzed types of soil was evaluated with the ANOVA analysis of variance, using the software package Statistica 8.0 PL. In order to describe changeability of *Carabidae* assemblages dwelling on the analyzed types of soil, different in soil parameters, ordinance techniques were used with an aid of the software package Canoco v. 4.5 (TER BRAAK 1986). The statistical significance of canonical axes was established with Monte Carlo tests.

RESULTS AND DISCUSSION

The soils present in the analyzed peatland belong to the division of hydrogenic soils (division IV), to the order of bog (order IVa) and post-bog soils (order IVb). The latter soil was represented by the type of muck soils, subtype of peat-muck (GMT1 and GMT2) soils and by mucky soils belonging to the subtype of muckous soils. Bog soils are the peat soils of lowland bogs, characterized by active accumulation of organic sedmients (e.g. peat), which can accumulate to over 30 cm in thickness. The peat soil found in the centre of the analyzed area was developed from lowland, rush peat, moderately (R2) and strongly (R3) decomposed. Post-bog soils, in turn, are formed from bog soils, which have been drained. In such soils, the muck formation process occurs due to the penetration of air into soil pores in the upper soil horizones. The peat-muck soils found in Stary Dwór were formed from mucky rush peats. The thickness of the peat muck varied from 21 to 40 cm. Muckous soils (GM) are a further stage in the development of post-bog soils in the decession phase. They contain between 3-10% of organic matter (peat and muck-peat soils have over 20% organic matter). The organic matter has the characteristics of peat muck and does not form complex bonds with the mineral components of soil. In the analyzed soil, the muckous formation lay on a loose sand substrate 30 cm deep into the soil profile. The properties of the analyzed soils depended on their position of the relief, advancement of the muck formation process and content of organic matter (Table 1). The highest soil ash content in the surface horizons was in the muckous soil (90.39%), and the lowest – in profile 3 of the peat-muck soil (18.77%). In the muckous soil, the ash content was rising with the depth, in contrast to the peat-muck and peat soils. The specific density of the peat-muck and peat soils rises with the depth, and ranges within 1.46-2.47 Mg m^{-3}. The specific density in the muckous soil varies from 2.45 do 2.68 Mg m^{-3}. The bulk

Table 1

Some properties of surface horizons of the soils in Stary Dwór peatland

Analyzed soil	pH (H_2O)	Ash content	Organic carbon (g kg^{-1})	Bulk density (Mg m^{-3})
	pH	Pop	M org	Vo
Muckous soil GM	7.2	903.9	5.57	1.4
Peat-muck soil GMT1	6.55	255.9	43.16	0.47
Peat-muck soil GMT1	6.6	187.7	47.12	0.26
Peat soils GT	6.23	312.9	39.86	0.44

density of the peat-muck and muck soils decreases with the depth. It ranges between 0.13 and 0.26 Mg m^{-3} in the surface layers. In the muckous soils, the bulk density attains the highest values (1.40-1.55 Mg m^{-3}). The total porosity was the lowest in the muckous soils, decreasing in deeper layers of the soil profile (42.86-36.74%). In the surface horizon of the peat-muck and peat soils, the total porosity was 67.81-88.89%. It rose in deeper layers of the soil, reaching the maximum value of 94.74% in the peat-muck soil at the depth of 21.42 cm. The reaction of the analyzed soils varied from slightly acidic to neutral. The lowest values of pH in H_2O and KCl were determined in the muckous soil. The reaction was decreasing towards the centre of the land depressing, reaching the lowest values in the peat soil. The soils of Stary Dwór bog area are characterized by a varied content of organic substance. The lowest concentration of organic matter was found in the muckous soil (9.60%). As the land inclined, the content of organic matter in soil rose. In mucks of the peat-muck soils, it was 74.41 to 81.23%, increasing in the layers of rush peat to 84.56-92.78%. In the peat soil, however, the content of organic matter rose in the deeper layers of the profile, ranging between 68.71% and 89.90%.

During the two-year observations carried out in Stary Dwór, a total of 673 specimens of *Carabidae* beetles representing 29 species were captured (Table 2). The analysis of variance demonstrated that the type of soil was a factor that significantly affected the number of captured carabid beetles (p=0.0222), but did not produce a significant effect (p=0.0818) on the qualita-

Table 2

Species composition and dominance (%) of the carabid beetles on the analyzed types of soil

Species		Muckous soil	Peat--muck soil GMT1	Peat-muck GMT2	Peat soils
Latin name	abbrev.				
Amara aenea (De Geer.1774)	A_aene	0.93	1.20	1.48	2.68
Amara communis (Panzer.1797)	A_comm	0.00	0.40	1.97	0.00
Amara convexior Stephens.1828	A_conv	0.00	0.40	1.48	0.89
Amara eurynota (Panzer.1797)	A_eryi	0.93	1.60	1.97	5.36
Amara familiaris (Duftschmid.1812)	A_famil	0.93	0.00	0.00	0.00
Amara ovata (Fabricius.1792)	A_ova	0.93	0.40	0.00	0.00
Amara similata (Gyllenhal.1810)	A_simi	0.00	1.60	1.48	1.79
Amara spreta Dejean.1831	A_spre	0.93	0.00	0.00	0.00
Amara tibialis (Paykull.1798)	A_tibi	0.00	0.00	0.00	1.79
Anisodactylus binotatus (Fabricius.1787)	An_bin	0.00	0.40	0.99	0.00
Calathus melanocephalus L.	C_melano	0.00	0.40	0.00	0.00
Calathus ambiguus (Paykull.1790)	C_amb	0.00	0.00	0.49	0.00
Carabus convexus Fabricius.1775	Ca_con	0.00	0.40	0.00	0.00
Carabus granulatus Linnaeus. 1758	Ca_gran	1.85	6.40	12.81	9.82
Carabus marginalis Fabricius.1794	Ca_marg	8.33	0.40	0.00	0.89
Carabus nemoralis O.F.Muller.1764	Ca_nemo	0.00	0.00	0.00	0.89
Carabus violaceus Linnaeus. 1758	Ca_viol	0.93	0.00	0.00	0.00
Curtonotus aulicus (Panzer.1797)	Cu_auli	0.00	0.00	0.49	0.00
*Cychrus caraboides (*Linnaeus.1758)	Cy_car	2.78	0.00	0.00	0.00
Harpalus rubripes (Duftschmid.1812)	H_rubri	0.93	0.00	0.49	0.00
Harpalus rufipes (De Geer.1774)	H_rufi	0.00	2.00	0.49	0.00
Harpalus signaticornis (Duftschmid.1812)	H_signa	0.93	0.00	0.00	0.00
Harpalus tardus (Panzer.1797)	H_tard	0.00	0.00	0.00	0.89
Nebria brevicollis (Fabricius.1792)	N_brev	0.00	0.00	0.49	0.00
Poecilus cupreus (Linnaeus.1758)	Po_cupr	11.11	19.60	7.88	8.04
Poecilus versicolor (Sturn)	Po_ver	55.56	46.00	56.16	44.64
Pterostichus melanarius (Illiger.1798)	P_melan	5.56	17.60	9.85	16.07
Pterostichus niger (Schaller.1783)	P_nige	7.41	1.20	0.99	4.46
Pterostichus nigrita (Paykull.1790)	P_nigr	0.00	0.00	0.49	1.79
Number of species		15	16	17	14
Number of individuals		108	250	203	112

tive composition of the analyzed *Carabidae* assemblages. Similar results of tests were reported by THIELE (1977), who concluded that the differences in the qualitative and quantitative composition of *Carabidae* living on light and heavy soils are larger than between assemblages of ground beetles dwelling on different types of crops. This dependence has also been confirmed by HOLOPAINEN et al. (1995), who studied communities of carabids in barley fields. Differences in the particle size distribution of soil seems to have influence on the number of captured carabid beetles. On sandy-loam soils, PAŁOSZ (2006) captured four times as many carabids as on sandy soil, without noticing any differences in the species composition between beetle communities from the two types of soils. In contrast, KOVAL and DUSEVA (2008) observed increased abundance of ground beetles on sandy soil compared to loamy soil. In addition, these authors found out that populations of *Carabidae* settling on the two types of soil were also different in the species composition and structure of dominance. In the present study, most of the individuals belonging to *Carabidae* were captured on the peat-muck soil (GMT1 – 250 individuals and GMT2 – 203 individuals). Significantly fewer individuals of the ground beetle family were captured on the peat soil (112 individuals) and the muckous soil (108 indiv.). The distribution of the numbers of captured species of *Carabidae* was similar. Most species were captured on the peat-muck soil in the two analzyed profiles (GMT1 – 16 and GMT2 – 17 species). The dominance structure is an important parameter in the evaluation of assemblages of *Carabidae* beetles. On the muckous soil, the superdominant species was *Poecilus versicolor* (55.56%) (Table 2). The eudominants included: *Poecilus cupreus*, which made up 11.11% of all captured individuals of *Carabidae*. The group of dominants consisted of 3 species: *Carabus marginalis*, *Pterostichus niger* and *Pterostichus melanarius*. On the peat-muck soils of both profiles, the superdominant species was *P. versicolor*, whereas the eudominant and dominant groups were composed of *P. cupreus*, *P. melanarius* and *Carabus granulatus*. On the peat soil, the composition of the species dominating in classes D6 – D4 was almost identical, except that another species, *Amara eurynota*, was added to the group of dominant species.

Our assessment of the dependences between the types of soil and the species of ground beetles captured on a given soil was based on ordinance analyses. The length of the gradient (SD = 3.756) established on the basis of the detrended correspondence analysis (DCA), implied a unimodal character of the distribution of data. The influence of particular properties of soil's surface layers on the captured ground beetles was evaluated according to the canonical correspondence analysis (CCA), the results of which suggested that the highest percentage of variability in the presence of the analyzed ground beetle species was described by an environmental variable, i.e. soil pH (Figure 1). This factor was most strongly correlated with the first ordinance axis and described 14.7% of the variability of the identified *Carabidae* species. The increasing soil pH was correlated with the occurrence of such species as *Carabus marginalis* and *Amara convexior*. The second ordinance

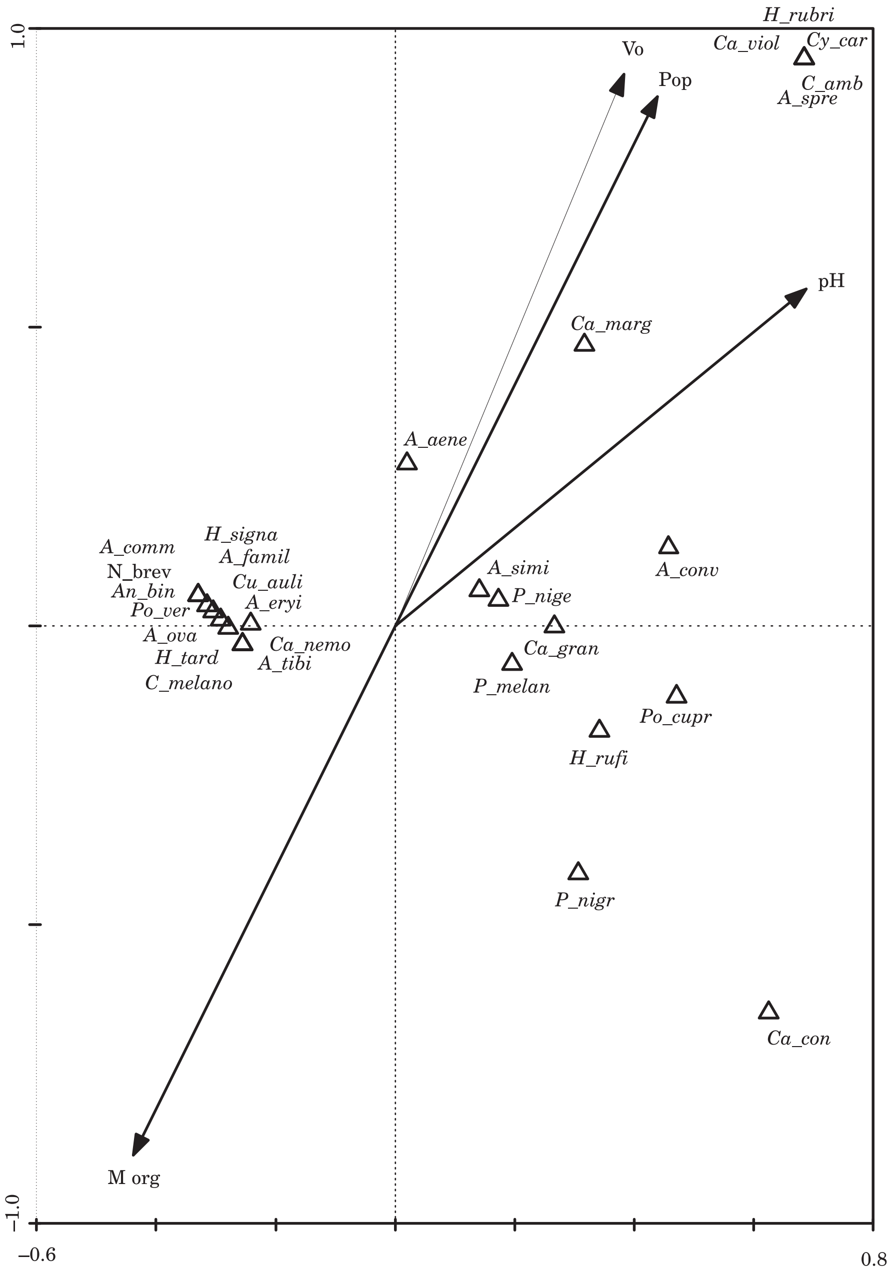

Fig. 1. Ordinance diagram of the canonical correspondence analysis (CCA) illustrating the dependence between presence of *Carabidae* species and parameters describing the analyzed types of soil. The statistical significance of cannonical axes was established according to Monte Carlo tests (p<0.1) Explanation of the abbreviations used in the diagram can be found under Tabs. 1 and 2

axis, which described smaller variability of the analyzed beetle assemblage than the first axis, was correlated with the bulk density of soil, its ash content and content of organic matter. Our search for the dependence between the type of soil and the species of *Carabidae* was based on the results of the canonical correspondence analysis (CCA). It has been found out that the soils representing the muck-peat type (GMT1 and GMT2) are wilingly penetrated by such species as *Carabus granulatus*, *Anisodactylus binotatus*, *Poecilus versicolor* and *Amara similata* (Figure 2). The muck type of soil (GM) was in turn associated with the presence of such species as *Amara ovata* and *A. eurynota*. *Harpalus rubripes* and *Pterostichus nigrita* correlated with another envioronmental factor, namely peat soils.

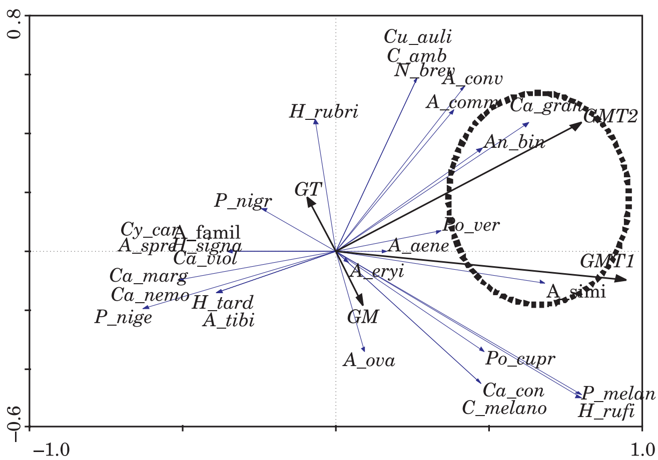

Fig. 2. Diagram of the detrended correspondence analysis (DCA) presenting the variability of the species composition depending on the analyzed soils.
(Explanation of the abbreviations of the species names used in the diagram can be found in Table 2)

The captured species of ground beetles were classified into specific ecological groups, according to their feeding, habitat or moisture requirements, type of development and geographical distribution. Based on the redundancy analysis (RDA) (the data were characterized by linear distribution), the authors tried to establish whether there was any dependence between the analyzed types of bog and post-bog soils and the presence of ground beetles belonging to specific ecological groups. It has been determined that the first ordinance axis correleated with the factor such as the muck-peat soils (GMT1 and GMT2) and peat soils (GT) (Figure 3). The muck-peat soils were correlated with the presence of hygrophilous carabid species, associated with peatlands and open areas. The muckous soils, however, were characterized by the presence of woodland species of ground beetles, mesoxerophilous species

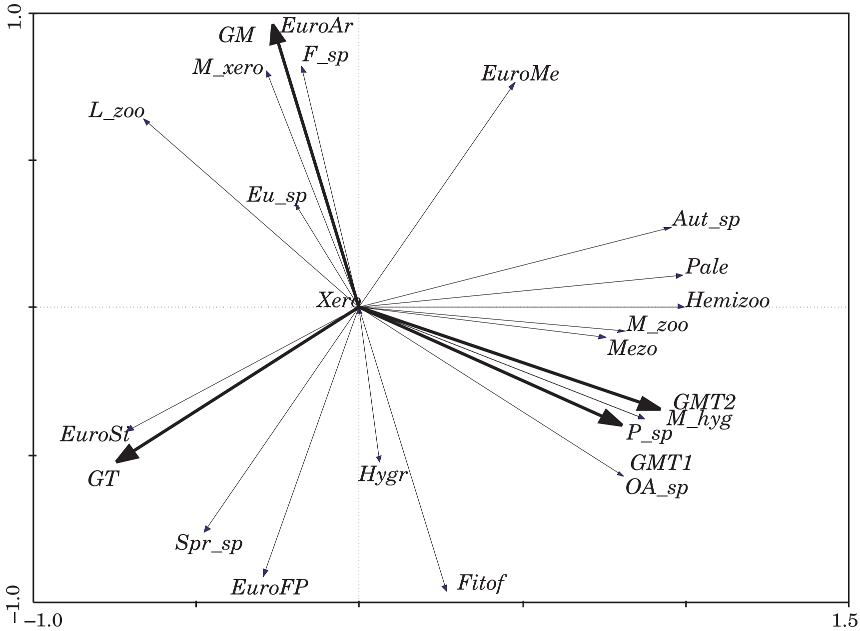

Fig. 3. Diagram of the redundency analysis (RDA) representing dependeces between the analyzed types of soil and *Carabidae* species ordered according to their ecological characteristics: L_zoo – Large zoophages, M_zoo – Medium zoophages, Hemizoo – Hemizoophages, Fitof – Phytophages, F_sp – Forest species, OA_sp – Open area species, P_sp – Peatbog species, Eu_sp – Eurytopic species, Xero – Xerophilic species, M_xero – Mesoxerophilic species, M_hygr – Mesohygrophilic species, Hygr – Hygrophilic species, Pale – Palaearctic species, EuroAR – Euroarctic species, EuroSi – Euro – Siberian species, EuroMe – Euro – Mediterranean species, EuroFP – European Forest Province species, Spr_sp – Spring species, Aut_sp – Autumn species

living in the Euro-Arctic area. The peat soils were strongly correlated with the presence of Euro-Siberian species. This dependence was described by ALESKANDROWICZ (2002) and NIETUPSKI et al. (2008), who drew attention to the fact that an increasing share of Euro-Siberian species on peatlands was encouraged by results of some types of man's activity, for example land drainage systems and cut meadows.

CONCLUSIONS

1. The type of soil proved to be a factor that significantly influenced the number of captured individuals representing the family of *Carabidae*.

2. The decreasing pH gradient of the analyzed soils as well as the increasing soil content of organic carbon in the muckous, peat-muck and peat soils were associated with the decreasing number of carabid individuals less tolerant to the changing moisture conditions (mesophilous species), which were replaced by hygrophilous specimens.

3. As the soil's acidity and content of organic substance were increasing, so did the number of mixophagous at the expense of predatory individuals.

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