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FIELD AND FOREST WATER PONDS AS LANDSCAPE ELEMENTS AFFECTING THE BIODIVERSITY OF CARABID BEETLES (COL.; CARABIDAE)

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Key words: ground beetles, landscape, small water ponds, assemblages, diversity.

Abstract

The study was carried out in 2006, in Tomaszkowo near Olsztyn, north-eastern Poland. It comprised two small water ponds: A – in a forest, and B – in a field. Carabid beetles were caught into Barber's traps from May to October 2006. In total, 1408 individuals belonging to Carabidae were captured: 629 individuals representing 47 species around the forest pond and 779 individuals representing 56 species around the field pond. It has been concluded that small water bodies, which improve water relations in the landscape, can considerably influence the increased diversity of Carabidae, as well as stimulate the presence of rare and valuable stenobiotic species.

ŚRÓDPOLNE I ŚRÓDLEŚNE ZBIORNIKI WODNE JAKO ELEMENTY KRAJOBRAZU WPŁYWAJĄCE NA BIORÓŻNORODNOŚĆ BIEGACZOWATYCH (COL.; CARABIDAE)

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Key words: biegaczowate, krajobraz, małe zbiorniki wodne, zgrupowania, bioróżnorodność.

Abstract

Badania prowadzono w roku 2006 w Tomaszkowie koło Olsztyna w północno-wschodniej części Polski. Dotyczyły one dwóch małych zbiorników wodnych: A – oczko leśne i B – śródpolne. Chrząszcze z rodziny biegaczowatych odławiano do zmodyfikowanych pułapek glebowych typu Barbera od maja do końca października 2006 roku. W czasie badań odłowiono łącznie 1408 osobników Carabidae,

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629 osobników należących do 47 gatunków wokół zbiornika śródleśnego i 779 osobników należących do 56 gatunków z okolic zbiornika śródpolnego. Wyniki analizy ekologicznej ich zgrupowań wskazują, że pozostawianie i ochrona drobnych zbiorników wodnych w krajobrazie rolniczym lub leśnym może mieć korzystny wpływ na zasiedlające je zgrupowania epigeicznych biegaczowatych, wyrażający się przede wszystkim zwiększeniem różnorodności gatunkowej Carabidae oraz pojawieniem się gatunków rzadkich i o wąskim zakresie tolerancji względem wilgotności siedliska.

Introduction

In the natural environment, so often re-shaped by people, the fragmentation of habitats is a frequent development. For biodiversity, this is definitely a positive consequence. In spatially diversified habitats, there are many half-empty niches, which facilitate easy adaptation and help to sustain greater diversity and species richness among animals (TEWS et al. 2004, TWARDOWSKI et al. 2009). The preservation of various water bodies or wetlands with their plant cover in the spatial landscape structure means the conservation of valuable natural habitats owing to the contained flora and fauna. An important group of animals representing epigeic fauna are the beetles of the family Carabidae, because most of them are predators able to withhold gradations of phytophags, both forest dwelling ones and those which inhabit agricultural biocenoses. They are also a popular zoological bioindicators (THIELE 1977, RAINIO and NIEMELA 2003, KOTZE et al. 2011).

The purpose of this study has been to describe communities of Carabidae dwelling near shores of small water ponds lying in fields and forests. It seemed important to pay more attention to such apparently inconspicuous objects as small ponds situated in various habitats, and their role in the formation of assemblages of ground beetles living around these water bodies.

The following research hypotheses were made for studied sites:

1. The areas adjacent to forest water bodies differ in species abundance of Carabidae from areas with midfield ponds.

2. The presence of small water reservoirs in the landscape fosters the appearance of stenobiontic species both in the forests and in open areas.

Methods and research area

The observations were carried out in 2006, in a village called Tomaszkowo, situated near Olsztyn (UTM DE 65), in north-eastern Poland. The study comprised two small water bodies: A – a pond in a forest, and B – a pond in a field. The former covered an area of 0.4 ha and was surrounded by about 70-year-old mixed fresh forest with the dominant pine (*Pinus sylvestris* L.).

The pond shores were overgrown with alder (*Alnus glutinosa* Gaertn.), rowans (*Sorbus aucuparia* L.) and oaks (*Quercus robur* L.); the shrubs were mostly composed of willow (*Salix alba* L.). The understory was found to comprise raspberries (*Rubus idaeus* L.), nettles (*Urtica dioica* L.) and impatiens (*Impatiens noli-tangere* L.). The second object (B) was a field pond with the surface area of 0.3 ha, supplied by rainfalls and largely overgrown with reeds (*Phragmites australis* (Cav.) Trin. ex Steud.). To the north, it bordered with a tree assemblage growing on 0.2 ha of a field and composed of such species as alder (*Alnus glutinosa* Gaertn.), birch (*Betula pendula* Roth.), poplar (*Populus alba* L.), ash (*Fraxinus excelsior* L.). The lower level consisted of willow (*Salix alba* L.), European black elder (*Sambucus nigra* L.), plum trees (*Prunus spinosa* L.), raspberries and blackberries (*Rubus idaeus* L., *Rubus plicatus* Weihe Nees), and dog rose (*Rosa canina* L.). The herbal plants included bulrush (*Scirpus sylvaticus* L.), sedge (*Carex hirta* L.), tussock-grass (*Poa pratensis* L.), cocksfoot (*Dactylis glomerata* L.). The investigated pond was surrounded by arable fields cropped with rye, wheat and barley.

The research material was captured into the Barber's traps from May to October. The traps were emptied every 10 days. Five traps were placed along the shores of each pond, about 2–5 m from the water table. In small water bodies located in forest (A), trap A1 was set at the edge of the forest, about 30 m from a forest meadow. The subsequent traps (A2 to A5) were set every 20-30 m along the shores of the pond. In study area located among fields (B), traps B1, B2 and B3 were set between the pond and fields, trap B4 was placed at the edge of the tree community and B5 was inside that groups of trees, on the edge of the water pond (Figure 1).

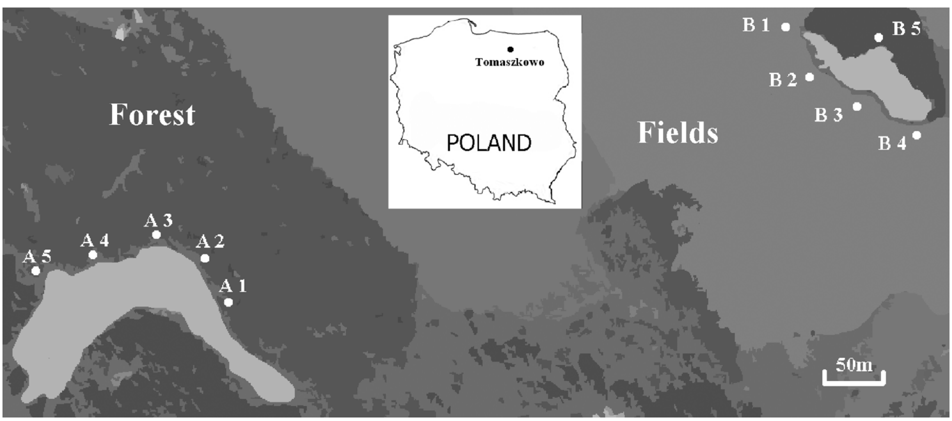

Fig. 1. Localization of study sites and the layout of Barber's traps (A1-A5 – traps around the pond in a forest, B1-B5 – traps around the pond in a field)

The material was species classified according to the keys by PAWŁOWSKI (1974), WATAŁA (1995) and HŮRKA (1996), using the terminology developed by ALEKSANDROWICZ (2004). The captured specimens of Carabidae were analyzed in terms of species composition and dominance structure. The following dominance classes were distinguished: dominants (<5%), subdominants (3>5%), recedents (1>3%), subrecedents (>1%). The ecological classification of the caught carabid beetles was made according to their preferences with respect to feeding, habitat, humidity and type of development. When describing the results, the Shannon's diversity index (H'), the Pielou index of evenness (J') and dominance index by Simpson (D) were applied. The significance of differences between the mean values of these indices and the abundance and number of species was assessed with a one-factorial analysis of variance ANOVA. The dependence between structure of Carabidae assemblies and type of habitat was determined by redundancy analysis (RDA) (TER BRAAK 1986). The RDA method had been selected based on the analysis of data distribution (DCA). The RDA method was applied to arrange the data and demonstrate relationships between the caught Carabidae species and habitat-specific features (distance to the forest – Forest; distance to the fields – Fields and presence of woodlots – Woodlots). The statistical significance of canonical axes was verified by the Monte Carlo test. All statistical calculations and their graphic interpretation were performed using the software packages Statistica 10 PL and Canoco 4.56 (TER BRAAK and MILAUER 1998).

Results

In total, 1408 Carabidae individuals were captured, including 629 individuals from 47 species around the forest pond and 779 individuals from 56 species around the field pond (Table 1). No statistically significant differences in the number of individuals and species, as well as in the average values of the examined indicators of the diversity between the studied habitats were observed. High values of the Shannon (H') (A – 2.95; B – 3.08) and Pielou (J') (A – 0.77; B – 0.77) indices prove quite large species diversity and evenness of the examined habitats. The Simpson index (D), had rather low values in the analyzed environments (A – 0.08; B – 0.07), possibly implying large stability of the observed communities of Carabidae. The same conclusion can be drawn from the structure of dominance (tab. 2). Although the share of dominants in both environments was high (54 and 64%), it is divided between several species, none of which obtaining dominance values high enough to distort the structure of a whole assemblage. Forest zoophages beetles prevailed in the group of carabid beetles found around the field water pond. The species attaining the highest share was *Pterostichus oblongopunctatus* (19.87%), a forest, medium-size zoophages beetle. The high moisture of studied sites favours frequent presence of hygrophilous species, like *Agonum fuliginosum* and *Oxypselaphus obscurus*. In the vicinity of the forest pond, the dominant species were mostly open area Carabidae. The highest shares were achieved by the aphid-eating, medium-size zoophages beetle *Anchomenus dorsalis* (12.07%).

Table 1

Species composition and number of individuals of Carabidae caught in the studied area

Species	Abbreviation	Pond in a forest (A)		Pond in a field (B)	
		n	D*(%)	N	D (%)
1	2	3	4	5	6
Agonum ericeti (Panzer,1809)	Ag_eri	0	0.00	1	0.13
A. fuliginosum (Panzer,1809)	A_ful	67	10.65	25	3.21
A. sexpunctatum (Linnaeus,1758)	Ag_sex	1	0.16	0	0.00
Amara aenea (Degeer,1774)	Am_aen	3	0.48	6	0.77
A. aulica (Panzer,1797)	Am_aul	0	0.00	1	0.13
A. bifrons (Gyllenhal,1810)	Am_bif	0	0.00	1	0.13
A. communis (Panzer,1797)	Am_com	12	1.91	2	0.26
A. convexior Stephens,1828	Am_conv	3	0.48	11	1.41
A. littorea Thomson,1857	Am_litt	1	0.16	0	0.00
A. lunicollis Schiodte,1837	Am_lun	15	2.38	8	1.03
A. plebeja (Gyllenhal,1810)	Am_ple	12	1.91	2	0.26
A. similata (Gyllenhal,1810)	Am_sim	0	0.00	2	0.26
Anchomenus dorsalis (Pontoppidan,1763)	Anch_dor	1	0.16	94	12.07
Anisodactylus binotatus (Fabricius,1787)	Ani_bin	1	0.16	0	0.00
Asaphidion flavipes (Linnaeus,1761)	Asa_fla	0	0.00	6	0.77
Badister lacertosus (Sturm,1815)	Bad_lac	3	0.48	2	0.26
Bembidion femoratum (Sturm,1825)	Bem_fem	0	0.00	1	0.13
B. lampros (Herbst,1784)	Bem_lam	3	0.48	1	0.13
B. properans (Stephens,1828)	Bem_prop	1	0.16	2	0.26
Calathus ambiguus (Paykull,1790)	Cal_amb	1	0.16	0	0.00
C. fuscipes (Goeze,1777)	Cal_fus	11	1.75	22	2.82
C. melanocephalus (Linnaeus,1758)	Cal_mel	1	0.16	0	0.00
Carabus arcensis (Herbst,1784)	Car_arc	4	0.64	1	0.13
C. cancellatus (Illiger,1798)	Car_can	1	0.16	2	0.26
C. granulatus (Linnaeus,1758)	Car_gra	53	8.43	64	8.22
C. hortensis (Linnaeus,1758)	Car_hor	38	6.04	37	4.75
C. nemoralis (O.F.Muller,1764)	Car_nem	2	0.32	25	3.21
C. violaceus (Linnaeus,1758)	Car_vio	11	1.75	1	0.13
Clivina fossor (Linnaeus,1758)	Cli_fos	0	0.00	1	0.13
Cychrus caraboides (Linnaeus,1758)	Cych_car	13	2.07	11	1.41
Dicheirotrichus placidus (Gyllenhal,1827)	Dich_pla	0	0.00	1	0.13
Dolichus halensis (Schaller,1783)	Dol_hal	1	0.16	1	0.13
Harpalus affinis (Schrank,1781)	H_aff	0	0.00	2	0.26
H. griseus (Duftschmid,1812)	H_gri	1	0.16	0	0.00
H. laevipes (Dejean,1829)	H_lea	2	0.32	8	1.03
H. latus (Linnaeus,1758)	H_lat	0	0.00	4	0.51
H. rubripes (Duftschmid,1812)	H_rub	0	0.00	8	1.03
H. rufipalpis (Sturm,1818)	H_rufip	0	0.00	1	0.13

cont. Table 1

1	2	3	4	5	6
H. rufipes (Degeer,1774)	H_ruf	24	3.82	13	1.67
H. tardus (Panzer,1797)	H_tar	0	0.00	5	0.64
Leistus terminatus (Hellwig,1793)	Lei_term	0	0.00	2	0.26
Limodromus assimilis (Paykull,1790)	Lim_as	29	4.61	63	8.09
Loricera pilicornis (Fabricius,1775)	Lo_pil	5	0.79	4	0.51
Nebria brevicollis (Fabricius,1792)	Ne_brevi	2	0.32	4	0.51
Notiophilus palustris (Duftschmid,1812)	N_pal	2	0.32	3	0.39
Oodes helopioides (Fabricius,1792)	Oo_hel	1	0.16	4	0.51
Oxypselaphus obscurus (Herbst,1784)	Oxy_obs	31	4.93	10	1.28
Panagaeus bipustulatus (Fabricius,1775)	Pan_bipu	0	0.00	1	0.13
Patrobus atrorufus (Strom,1768)	Pat_atr	2	0.32	0	0.00
Poecilus cupreus (Linnaeus,1758)	Po_cupr	3	0.48	59	7.57
P. lepidus (Leske,1785)	Po_lepi	9	1.43	1	0.13
P. versicolor (Sturm,1824)	Po_ver	11	1.75	51	6.55
Pterostichus aethiops (Panzer,1797)	Pt_aeth	0	0.00	1	0.13
P. anthracinus (Illiger,1798)	Pt_anth	2	0.32	6	0.77
P. diligens (Sturm,1824)	Pt_dil	1	0.16	3	0.39
P. melanarius (Illiger,1798)	Pt_mela	59	9.38	88	11.3
P. minor (Gyllenhal,1827)	Pt_min	12	1.91	4	0.51
P. niger (Schaller,1783)	Pt_nig	31	4.93	11	1.41
P. nigrita (Paykull,1790)	Pt_nigr	2	0.32	7	0.9
P. oblongopunctatus (Fabricius,1787)	Pt_oblo	125	19.89	79	10.14
P. quadrifoveolatus (Letzner,1852)	Pt_quadr	1	0.16	0	0.00
P. rhaeticus (Heer,1838)	Pt_rhae	0	0.00	2	0.26
P. strenuus (Panzer,1797)	Pt_stre	14	2.23	2	0.26
Synuchus vivalis (Illiger,1798)	Syn_viv	0	0.00	2	0.26
Trechus quadristriatus (Schrank,1781)	Tre_qua	1	0.16	0	0.00
Number of individuals		629		779	
Number of species		47		56	
Shannon' diversity (H') (Log Base 2,718)		2.95		3.08	
Evenness Pielou J'		0.77		0.77	
Simpson's Diversity (D)		0.08		0.07	

*D [%] – dominance coefficient

While searching for dependences between habitat conditions and the occurrence of Carabidae species, the redundancy analysis (RDA) was carried out. By analyzing the presence of particular Carabidae species in the context of varied habitat conditions such as the presence of fields, forests or groups of trees, groups of species characteristic for the specific habitats were clearly distinguished.

The presence of trees and shrubs as well as such common species as *Pterostichus melanarius, Harpalus rufipes* and *Limodromus assimilis* was positively correlated with the first ordination axis, describing almost 46% of the variation (fig. 2). In addition, the distribution of species in the diagram RDA, especially correlation of higrophilic species such as *Pterostichus nigrita, P. rhaeticus, P. aethiops* and *P. diligens* with the I ordination axis may indicate that habitat humidity is a factor strongly influencing the occurrence of ground beetles assemblages and stenotopic species.

Table 2

Share of carabid beetles in the studied areas according to the dominance classes

Dominance class	Pond in a forest (A)		Pond in a field (B)	
	Species	D*[%]	Species	D*[%]
Dominant species (<5%)	*Pterostichus oblongopunctatus*	19.87	*Anchomenus dorsalis*	12.07
	Agonum fuliginosum	10.65	*Pterostichus melanarius*	11.30
	Pterostichus melanarius	9.38	*Pterostichus oblongopunctatus*	10.14
	Carabus granulatus	8.43	*Carabus granulatus*	8.22
	Carabus hortensis	6.04	*Limodromus assimilis*	8.09
			Poecilus cupreus	7.57
			Poecilus versicolor	6.55
		54.37		63.93
Sub-dominant species (3>5%)	*Oxypselaphus obscurus*	4.93	*Carabus hortensis*	4.75
	Pterostichus niger	4.93	*Carabus nemoralis*	3.21
	Limodromus assimilis	4.61	*Agonum fuliginosum*	3.21
	Harpalus rufipes	3.82		
		18.28		11.17
Recedent species (1>3%)	10 gatunków	19.08	9 gatunków	13.09
Sub-recedent species (>1%)	28 gatunków	8.27	37 gatunków	11.81

*D [%] – dominance coefficient

The second ordination axis, describing over 30% of the variation, was found to correlate positively with the vicinity of fields. This variable was associated with a whole series of carabid beetles demonstrating highly varied habitat requirements.

Based on the results of the RDA, an attempt was made to verify whether there is any relationship between habitat conditions and the presence of specific ecological groups of Carabidae (Figure 3).

It was shown that trap B5, located on the edge of the water body, in a group of trees adjacent to the observed field pond, was most strongly correlated with the first ordination axis. Probably the tree patch gave shelter to many specimens representing various ecological groups of Carabidae. There were large and medium zoophages, eurytopic species and species dwelling on peat bogs among the captured specimens.

The second canonical axis corresponded to the presence of open area carabids, which in some sense was connected with trap B3, situated between the pond and an arable field. Negative correlation was observed between the second ordination axis and the forest pond. To the north-east, this pond was adjacent to a small xerothermic meadow, which was manifested by the presence of small zoophages beetles, typical of field and meadow habitats, in trap A1, which was the closest to the said meadow.

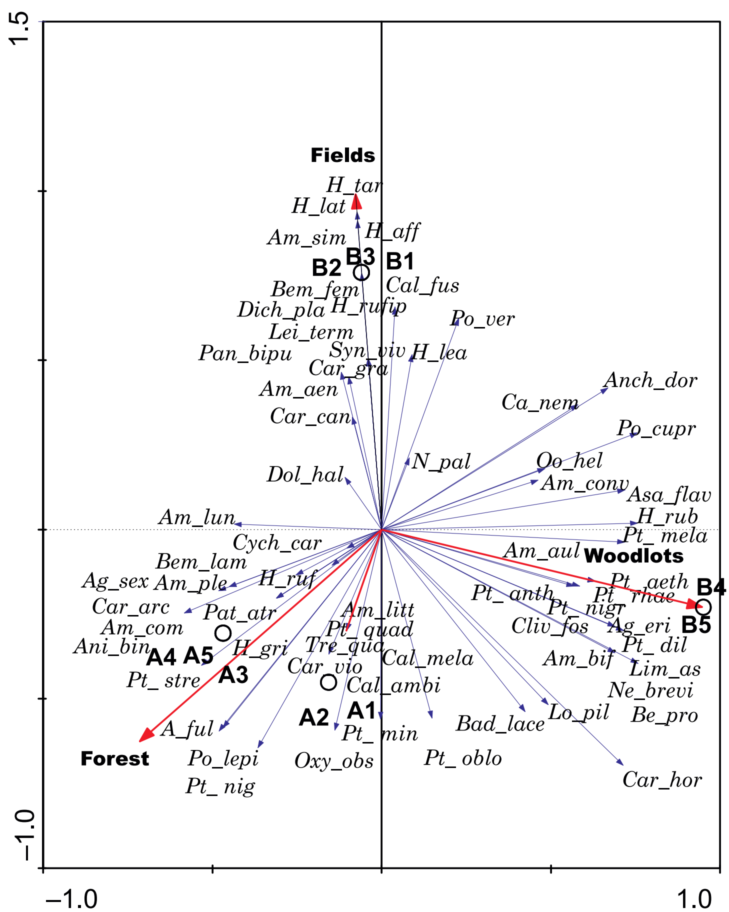

Fig. 2. Diagram of RDA analysis for the examined assemblages of Carabidae and selected environmental variables. Explanation and abbreviations of species are given in Table 1 and methods

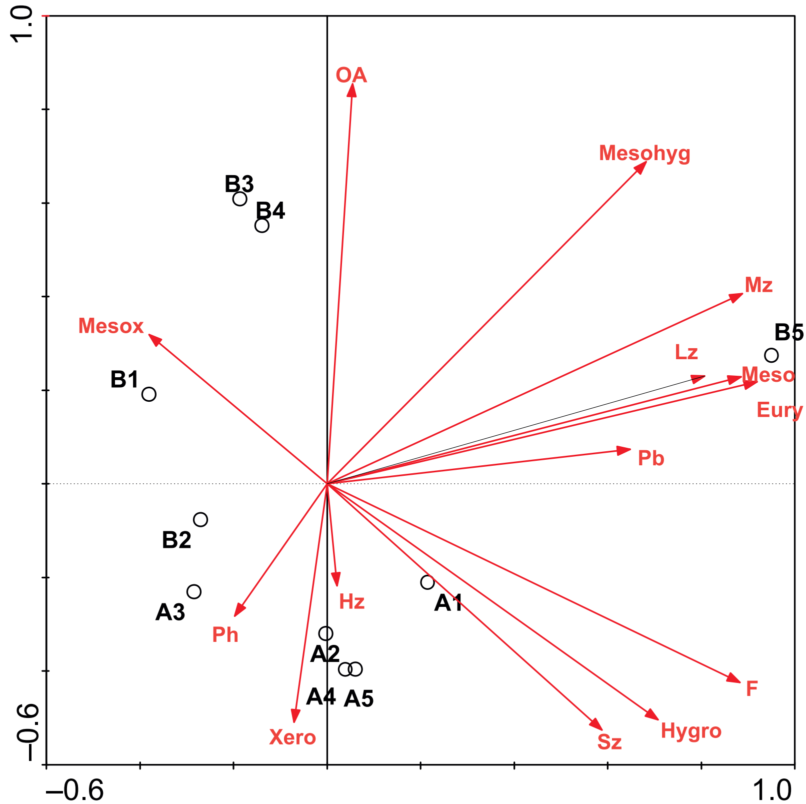

Fig. 3. Diagram of the redundancy analysis of RDA representing dependences between the analyzed habitats and ecological groups of Carabidae (Lz – Large zoophages, Mz – Medium zoophages, Sz – Small zoophages, Hz – Hemizoophages, Ph – Phytophages, F – Forest species, OA – Open area species, Pb – Peatbog species, Eury – Eurytopic species, Xero – Xerophilous species, Mesox – Mesoxerophilous species, Meso – Mesophilous species, Mezohyg – Mesohygrophilous species, Hygro – Hygrophilous species)

Discussion

In this study the hypothesis was not confirmed that the areas adjacent to forest water bodies differ in species richness of Carabidae from areas with midfield ponds. Despite the fact that near the midfield ponds more species of beetles than in the forest were recorded, these differences were not statistically significant. However high values of Shannon species diversity index should be noted in both the examined sites. In other studies on Carabidae of fields and woodlots from Tomaszkowo (KOSEWSKA at al. 2006, 2007, 2008, 2009) significantly lower values of this index were observed, in the fields, as well as wooded areas. This may prove that this type of habitat is very valuable for biodiversity conservation.

Small water bodies located in different habitats may appear to be rather inostensible landscape components, but more thorough examination will reveal their substantial influence, e.g. on the occurrence of Carabidae. Nowadays, when agriculture grows dynamically, swamps, peat bogs and other wetland habitats – due to drainage works and water retention engineering – are among disappearing habitats, which leads to a complete loss of peat-dwelling fauna and its transformation into a less valuable variant of carabid assemblages associated with fields (ALEKSANDROWICZ 2002). Even small water bodies, by improving water relations in the natural environment, contribute to a more numerous appearance of moisture favouring ground beetles which was confirmed in the studies. JĘDRYCZKOWSKI and KUPRYJANOWICZ (2005) argue that as the relative humidity of a habitat increases, so does the number of beetle species. Also, WOJAS (2008) reveals the richness of carabid fauna on the shores of stagnant water bodies and all types of wet and muddy environments. NIETUPSKI et al. (2007) observed carabid communities dwelling on cut meadows characterized by different moisture content and noticed more species on a very moist meadow lying by a water body. Such habitats, apart from species highly adaptable to different conditions, are inhabited by stenotopic Carabidae (JASKUŁA and STĘPIEŃ 2012).

The species composition of assemblages of Carabidae is often determined by the spatial differentiation of habitats (DUELLI et al. 1999, SKŁODOWSKI 2002). The composition and number of beetles translate directly to the structure of dominance of the examined assemblages. In the habitats analyzed in the current study, percentages of individual Carabidae species were quite even. There were no cases of extremely high shares of some of the dominant species, which could disturbe the structure of a whole community. The low rate Simpson's index, which pays more attention to common species while underestimating rare ones also indicates that. There were quite numerous species classified as recedent and subrecedent groups, a finding which – according to TROJAN (1999) – confirms that habitats located within a given territory are diverse. Small water ponds are most often associated with characteristic plants, shrubs and groups of trees. Ground beetles can use the examined habitats as a shelter, a place suitable for their development or a source of food in time periods with poorer food supplies (most often plant pests) on fields and in forests. Notable is the fact that some rare hygrophilous species e.g. *Oodes helopioides*, *Dicheirotrichus placidus* and *Agonum ericeti* were detected near the field pond. *Agonum ericeti* is recognized as a typically tyrphobiontic species (LINDROTH 1945, ALEKSANDROWICZ 2004, DREES et al 2007) so its presence in the studied habitat is all the more valuable. Therefore maintaining and protecting small water bodies on farmland or woodland may have a favourable influence on the epigeic ground beetles dwelling in such habitats, which could manifest itself by a raised species diversity of Carabidae and the occurrence of rare species as well as the ones which have a narrow tolerance range in terms of habitat humidity.

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