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Materials to the knowledge of the aquatic beetle fauna (Coleoptera) in mid-western Poland (Lubuskie Province)

Materiały do poznania chrząszczy wodnych (Coleoptera) Polski środkowo-zachodniej (województwo lubuskie)

SUMMARY

Although aquatic beetles are one of the most diverse groups significantly contributing to species diversity in freshwaters, their occurrence and distribution has been studied very poorly in mid-western Poland. Consequently, our knowledge about the current aquatic beetle species richness and habitat preferences is still scarce in large parts of this region. To close this knowledge gap, we investigated a selected area of approximately 500 km^2 in the south-western part of the Lubuskie Province, part of the Wielkopolsko-Kujawska Lowland, to obtain the richness of total, protected, endangered and rare species of aquatic beetles, as well as to analyse their diversity and ecological groups in representative habitats. For the study, 70 sampling sites representing ditches (5 localities), streams (4), rivers (13), small water bodies in open landscapes (7) and in forests (6), temporary (8) and permanent (7) fish ponds, lakes (4), fens (1), peat bogs (13) and marshes (2) were investigated from April to September 2011. In total, 115 species, including 10 protected by law or/and listed on the Polish Red List, as well as 11 rare and local in Poland species were found in the study area. Among them special attention should be paid to *Macroplea appendiculata* – a recently-discovered for the Wielkopolsko-Kujawska Lowland and critically endangered in Poland species as well as *Rhantus incognitus* – an endangered and rare species in Poland. The most frequent species was *Hyphydrus ovatus* (34.3% of sites), whereas 29 species, mostly stenotopic specialists, were recorded in only one site. Eurytopes and tyrphophiles were both present in each habitat type. Further, the most diverse habitats were temporary ponds containing 7 groups of stenotopes, whereas in streams only 2 groups were found. On average, the most species rich habitats were permanent ponds (median = 11 species) and bogs (11), but the highest species numbers were found in a temporary pond (44 species) and in a small water body in open landscape (42). The lowest species richness was found in streams (maximum 4 species per site). According to an evaluation of habitat types based on protected, threatened

and rare species, the most important were permanent and temporary ponds in the forested, water-rich parts of the study area. In agriculturally dominated parts, however, small rivers and occasionally small water bodies were of high importance for rare species.

We conclude that the species richness and abundance of protected, endangered and rare species are high in the study area in comparison to other parts of Poland. The most important habitats in terms of high diversity of aquatic beetles are predominantly permanent fish ponds and bogs, whereas permanent and temporary fish ponds play a key role for the high content of rare and protected species in the area.

Keywords: diversity, species richness, freshwaters, ponds, rare species, endangered species, protected species, *Macroplea appendiculata*, *Rhantus incognitus*

STRESZCZENIE

Chrząszcze wodne są jedną z najbardziej bogatych w gatunki grup znacząco przyczyniających się do różnorodności gatunkowej w wodach słodkich, jednak ich występowanie i rozmieszczenie w Polsce środkowo-zachodniej było badane w bardzo małym zakresie. W konsekwencji nasza obecna wiedza o ich różnorodności gatunkowej oraz preferencjach siedliskowych w tej części kraju jest znikoma. W związku z tym przeprowadzono inwentaryzację wybranego terenu o powierzchni ok. 500 km^2 w południowo-zachodniej części województwa lubuskiego, według Katalogu fauny Polski leżącego na Nizinie Wielkopolsko-Kujawskiej. Celem badań było określenie różnorodności gatunkowej oraz udziału gatunków chronionych, zagrożonych i rzadkich, a także analiza grup ekologicznych chrząszczy wodnych w reprezentatywnych biotopach. Próby pobrano z 70 stanowisk reprezentujących: rowy (5 stanowisk), strumienie (4), rzeki (13), oczka wodne w terenie otwartym (7) i śródleśnym (6), stawy rybne z okresowym (8) i permanentnym (7) stanem wody, jeziora (4), torfowiska niskie (1), torfowiska sfagnowe (13) oraz bagna (2) w okresie od kwietnia do września 2011 r. Stwierdzono 115 gatunków, w tym 10 gatunków chronionych lub/i uwzględnionych w Polskiej Czerwonej Liście oraz 11 gatunków rzadkich i lokalnych w Polsce. Na szczególną uwagę zasługują *Macroplea appendiculata* – gatunek krytycznie zagrożony (CR), chroniony oraz nowy dla Niziny Wielkopolsko-Kujawskiej, oraz *Rhantus incognitus* – gatunek zagrożony (EN) i rzadko spotykany w kraju. Najwyższa frekwencja cechowała *Hyphydrus ovatus* (34,3% stanowisk), natomiast 29 gatunków, w większości stenotopów, występowało tylko na jednym stanowisku. Spośród grup ekologicznych, eurytopy i tyrfofile występowały we wszystkich typach siedlisk. Najbardziej różnorodne pod względem typów ekologicznych chrząszczy były stawy okresowe, w których zanotowano 7 grup stenotopów. Najmniej stwierdzono ich w strumieniach (2 grupy). Średnio, największą ilością gatunków charakteryzowały się stawy permanentne (mediana = 11 gatunków) oraz torfowiska (11), natomiast maksymalnie najwięcej gatunków zanotowano w stawach okresowych (44 gatunki) oraz w małych zbiornikach terenów otwartych (42). Najmniej bogate gatunkowo były strumienie (maksymalnie 4 gatunki na stanowisko). Wyniki ewaluacji typów siedlisk pod kątem występowania gatunków chronionych, zagrożonych i rzadkich wykazały, że najbardziej istotne były permanentne i okresowe stawy na obszarach zalesionych i bogatych w wody. Jednak w obrębie dominacji agrocenoz, ważne dla zachowania tych grup gatunków okazały się małe rzeki oraz częściowo małe zbiorniki.

Na podstawie przeprowadzonych badań należy stwierdzić, że obszar środkowo-zachodniej Polski charakteryzuje się dużym bogactwem gatunków chrząszczy wodnych oraz dużym udziałem gatunków chronionych, zagrożonych i rzadkich na tle innych części kraju. Najważniejszymi typami siedlisk w aspekcie różnorodności gatunkowej są głównie stawy permanentne oraz torfowiska. Natomiast stawy okresowe i permanentne odgrywają kluczową rolę dla zachowania gatunków rzadkich na tym obszarze.

Słowa kluczowe: różnorodność, bogactwo gatunków, obszary słodkowodne, stawy, gatunki rzadkie, gatunki zagrożone, gatunki chronione, *Macroplea appendiculata*, *Rhantus incognitus*

INTRODUCTION

After flies (Diptera), aquatic beetles are the most heterogeneous and species-rich group of aquatic insects in freshwaters (62), and therefore significantly contribute to the biodiversity at the regional and global scale. In general, species richness of aquatic beetles depends on habitat heterogeneity, which provides sustainable conditions for both specialists and generalists on the regional scale (18, 24). Moreover, it has been shown that there is no one habitat type that is characterized by the highest species richness in all areas. For example, in the Roztocze Upland the rivers had the highest number of species (24), whereas in the Lubelska Upland small temporary ponds (16) and in Tuchola Forest fens and peat bogs (19) were the most species-rich habitats. Additionally, these habitats were also home to high numbers of protected and endangered species, which enhance their importance for developing conservation strategies.

Yet the current knowledge about the distribution of aquatic beetles is still very scarce in many regions of Poland. Related to this, available information from mid-western Poland, being a part of the Wielkopolsko-Kujawska Lowland, is based generally on historical data obtained more than 40 years ago and summarized in the "Catalogue of Polish Fauna" (26). Since then, no systematic studies revealing distribution patterns of aquatic beetles have been carried out, thus little has been reported from this area so far. Despite this, new species have been found in this faunistic region (93, 94), indicating an urgent need for exploratory studies in this part of Poland. Despite considerable landscape changes related to intensive agriculture and industry, there are still many semi-natural areas in this region. Although it is one of the biggest faunistic regions of Poland, some parts have either been investigated insufficiently or not at all. Conversely, in areas with a well-known distribution of aquatic beetles, systematic studies or investigations would allow to evaluate of an extent of the changes in diversity as well as to confirm the occurrence of particular species.

We chose an area of approximately 500 km^2 next to Gubin, Lubsko and Zasieki in the south-western part of the Lubuskie Province for our study. To our knowledge, neither historic nor current reports about aquatic beetles have been published for this part of Poland. Moreover, the high diversity of aquatic and semi-aquatic plant communities including many rare and endangered species indicated the unique character of this region (103) and its potential for containing suitable habitats for aquatic beetles. Consequently, the main purpose of our preliminary study was 1) to obtain the species-richness and abundance of protected, endangered and rare species of aquatic beetles, 2) to analyse the total species diversity as well as the diversity of groups of species associated with distinct environmental conditions in various habitat types in a selected area in mid-western Poland.

Within the scope of our study, only "true water beetles" *sensu* Jäch (57) were investigated. No systematic sampling of Chrysomelidae, classified to "phytophilous water beetles" (57) was carried out. Therefore, data concerning this family are only fragmentary in our study.

STUDY AREA

The study was carried out in the south-western part of Lubuskie district, in an area between Gubin, Lubsko and Zasieki (Fig. 1). According to the administrative division, almost all of the investigated area is enclosed by the Brody municipality, with only a few patches situated in the municipalities of Gubin (northern patch), Lubsko (eastern patch) and Tuplice (south-eastern patch).

According to geographical regionalisation of Poland (63), the northern part of the investigated area is localised in Gubińskie Elevations mesoregion, Zielonogórskie Elevations macroregion – reflecting the extreme position of the Vistulian glacial period. In contrast, the southern part belongs to

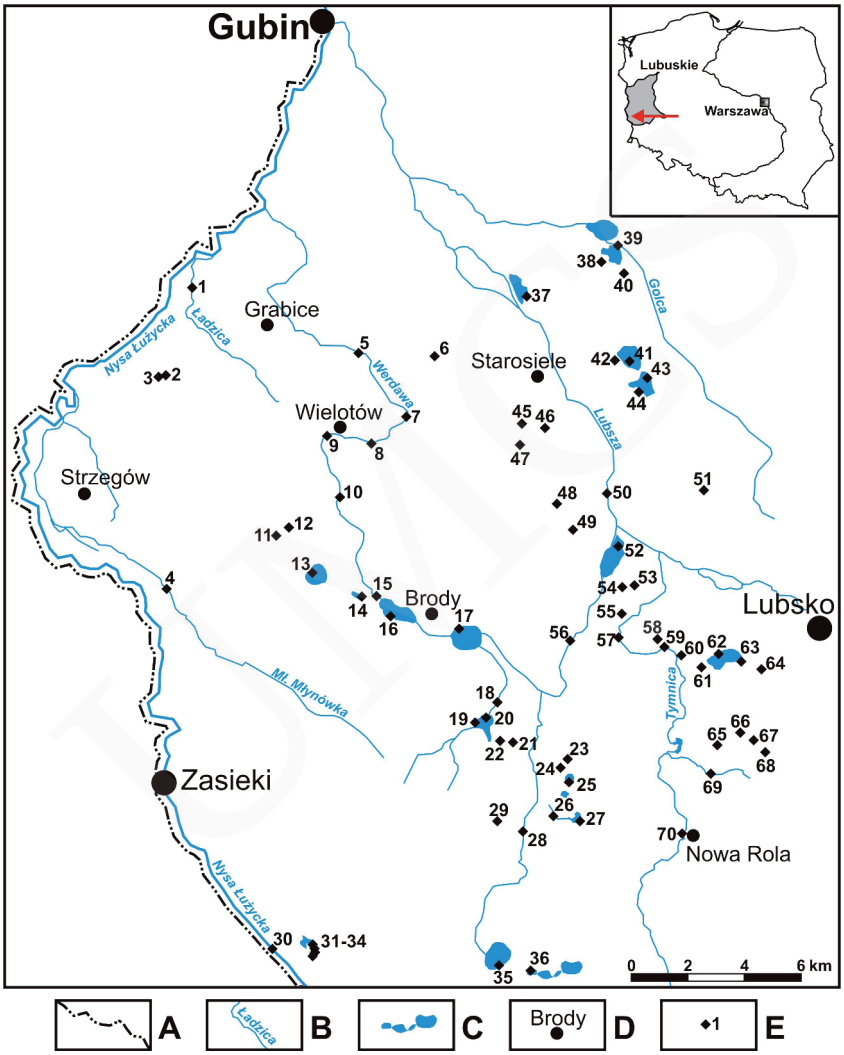

Fig. 1. Study area: A – Polish-German border, B – running waters, C – larger standing waters, D – localities, E – study sites.

Zasiecka Valley mesoregion, Lower Lusatia Depression macroregion and has been formed by an ice sheet during the Warthe Stage.

The investigated area is characterised by large forest complex with pine trees (*Pinus silvestris* L.) as the dominant tree group. Only next to Brody, Starosiedle, Grabice and Wielotów does agriculture dominate the landscape. The whole area is rich in running waters with various hydromorphological features. The largest river is Nysa Łużycka – classified as a mid-sized upland river due to its high slope of valley floor (105). Other running waters represent the type of lowland rivers dominated either by sandy (Ładzica, Werdawa, Mała Młynówka, Pstrąg, Tymnica, and Golca) or sandy-clayey (Lubsza) channel substrates (105). Among standing waters, there are numerous peat bogs, as well as

carp fish ponds and small water bodies in forests and open landscape. Additionally, only two lakes descending from the Vistulian glacial period are present next to Brody (76). These lakes are shallow (with maximum depths <2 m), eutrophic, and have partially swampy shores. Further, four small lakes are near the river Pstrąg, and are probably of anthropogenic origin.

For the present study 70 sampling sites representing broad spectrum of habitat types have been chosen to investigate the presence and diversity of aquatic beetles. In particular, ditches (Di) were investigated in 5 localities (No. 1, 12, 19, 44, 65); streams (St) – 4 (No. 18, 26, 66, 69); rivers (Ri) – 13 (No. 4, 5, 7, 8, 9, 10, 28, 30, 50, 56, 57, 60, 70); small water bodies in open landscape (Sw-o) – 7 (No. 2, 6, 32, 33, 45, 46, 47); small water bodies in forests (Sw-f) – 6 (No. 11, 29, 48, 49, 61, 67); temporary ponds (Po-t) – 8 (No. 17, 35, 36, 37, 41, 43, 52, 62); permanent ponds (Po-p) – 7 (No. 3, 14, 20, 31, 34, 39, 68); lakes (La) – 4 (No. 13, 16, 25, 27); bogs (Bo): fens – 1 (No. 59), *Sphagnum* bogs – 13 (No. 21, 22, 24, 38, 40, 42, 51, 53, 54, 55, 58, 63, 64), and marshes (Ma) – 2 (No. 15, 23), respectively (Fig. 1, Tab. 1).

Running waters fulfilling the assumptions of Water Directive were defined as rivers (105), whereas small natural running waters narrower than 1 m and with a small catchment (< 20 km^2) were defined as streams. Further, standing waters with the surface < 0.5 ha and no fish management were classified as small water bodies, whereas bigger artificial standing waters were classified as ponds. The category "temporary ponds" includes fish ponds that are cyclically drained during fish harvesting and refilled for stocking. In contrast, "permanent ponds" are either aquaculture ponds without seasonal drainage or permanent water bodies stocked with fish for angling.

MATERIAL AND METHODS

Aquatic beetles were collected from the end of April to September 2011. Two sampling methods were applied: 1) a net (diameter 35 cm, mesh size 1x1 mm) used for sampling in all study sites, and 2) bottle traps (volume of 5 litre) with bait (dried cat food) exposed for 12 hours (overnight) in selected standing waters. In total, 90 qualitative samples were taken. Individuals of protected species were identified immediately at sampling and returned to the water. All other individuals were stored in 70% ethanol and preserved for further identification. In total, 196 larvae and 3,051 imagines were collected, and 34 imagines of protected species were set free. Forty-five larvae could not be identified to the species level, hence those results are not reported. Species were identified according to keys from Freude et al. (36, with numerous later supplements), Galewski (38, 40, 41, 42), and Galewski and Tranda (43).

For faunistic analyses only qualitative data (based on species numbers or presence/absence), were used. For each species, frequency index (F_i) has been calculated as a quotient of site sums with species occurrence and sum of all investigated sites, here presented in percentages. The classification of species associated with distinct environmental conditions was performed according to Galewski and Tranda (43), Galewski (39), Nilsson and Holmen (78), Przewoźny et al. (91), and Więźlak (117).

To evaluate each site and further habitat types a point system referring to the current protection and threat state of particular species (21) was used. For this species protected by Polish law (103) from the Polish Red List of beetles (84), and rare in Poland (6) were taken. Points were assigned to particular species as follows: 5 points – species from the Habitat Directive; 4 – Red List species with categories CR-VU; 3 – Red List species with categories NT and LC; 2 – very rare and rare species in Poland; 1 – local species. Each species was taken into consideration only once with the highest point category. Points were summarised for each site and habitat type, giving information about the importance of the associated habitat for protected, endangered and rare species.

Tab. 1. Information on the geographical names (if present), habitat type (Di – ditch, St – stream, Ri – river, Sw-o – small water body in open landscape, Sw-f – small water body in forest, Po-p – permanent pond, Po-t – temporary pond, Bo – bog, Ma – marsh), the nearest village/town, UTM codes, and geographical coordinates (latitude and longitude) of sampling sites.

Site no.	Geographical name	Habitat type	Nearest village/town	UTM	Latitude (N)	Longitude (E)
1	-	Di	Sadzarzewice	VT74	51°52’47’’	14°39’45’’
2	-	Sw-o	Markosice	VT74	51°51’14’’	14°39’00’’
3	-	Po-p	Markosice	VT74	51°51’10’’	14°39’05’’
4	Mała Młynówka	Ri	Mielno	VT73	51°47’47’’	14°39’13’’
5	Werdawa	Ri	Kozów	VT84	51°51’40’’	14°44’36’’
6	-	Sw-o	Witaszkowo	VT84	51°51’46’’	14°46’24’’
7	Werdawa	Ri	Wierzchno	VT84	51°50’46’’	14°45’41’’
8	Werdawa	Ri	Wielotów	VT84	51°50’13’’	14°44’44’’
9	Werdawa	Ri	Wielotów	VT84	51°50’03’’	14°43’47’’
10	Werdawa	Ri	Kumiałtowice	VT84	51°49’18’’	14°43’54’’
11	-	Sw-f	Węgliny	VT74	51°48’42’’	14°42’08’’
12	-	Di	Węgliny	VT74	51°48’50’’	14°42’31’’
13	Suchodół	La	Suchodół	VT83	51°47’57’’	14°43’31’’
14	-	Po-p	Suchodół	VT83	51°47’42’’	14°44’22’’
15	-	Ma	Jeziory Dolne	VT83	51°47’35’’	14°44’48’’
16	Brody	La	Brody	VT83	51°47’23’’	14°45’37’’
17	-	Po-t	Nabłoto	VT83	51°47’08’’	14°47’19’’
18	-	St	Proszów	VT83	51°45’55’’	14°48’16’’
19	-	Di	Proszów	VT83	51°45’49’’	14°48’06’’
20	Ruskie Stawy	Po-p	Proszów	VT83	51°45’43’’	14°47’57’’
21	-	Bo	Proszów	VT83	51°45’21’’	14°48’49’’
22	-	Bo	Proszów	VT83	51°45’18’’	14°48’24’’
23	-	Ma	Proszów	VT83	51°45’06’’	14°50’15’’
24	-	Bo	Proszów	VT83	51°44’59’’	14°50’18’’
25	Głębokie	La	Proszów	VT83	51°44’44’’	14°50’09’’
26	-	St	Grężawa	VT83	51°44’02’’	14°50’02’’
27	Niwa	La	Grężawa	VT83	51°44’08’’	14°50’36’’
28	Pstrąg	Ri	Grężawa	VT83	51°43’52’’	14°49’06’’
29	-	Sw-f	Grężawa	VT83	51°43’59’’	14°48’20’’
30	Nysa Łużycka	Ri	Brożek	VT72/82	51°41’45’’	14°43’02’’
31	-	Po-p	Brożek	VT82	51°41’55’’	14°43’04’’
32	-	Sw-o	Brożek	VT82	51°41’55’’	14°43’02’’
33	-	Sw-o	Brożek	VT82	51°41’55’’	14°43’04’’
34	-	Po-p	Brożek	VT82	51°42’03’’	14°42’58’’
35	Duży Staw	Po-t	Tuplice	VT82	51°41’43’’	14°48’17’’
36	-	Po-t	Tuplice	VT82	51°41’28’’	14°49’27’’
37	-	Po-t	Gębice	VT84	51°52’47’’	14°48’48’’
38	-	Bo	Łazy	VT84	51°53’22’’	14°50’44’’

39	-	Po-p	Łazy	VT84/94	51°53’28”	14°51’17”
40	-	Bo	Łazy	VT94	51°53’10”	14°51’23”
41	-	Po-t	Lasek	VT94	51°51’48”	14°51’35”
42	-	Bo	Lasek	VT84/94	51°55’17”	14°52’32”
43	-	Po-t	Lasek	VT94	51°51’19”	14°52’03”
44	-	Di	Lasek	VT94	51°51’10”	14°52’02”
45	-	Sw-o	Jasienica	VT84	51°50’39”	14°48’44”
46	-	Sw-o	Jasienica	VT84	51°50’34”	14°49’25”
47	-	Sw-o	Jasienica	VT84	51°50’18”	14°48’45”
48	-	Sw-f	Grodziszcze	VT84	51°49’13”	14°49’47”
49	-	Sw-f	Biecz	VT84	51°48’51”	14°50’10”
50	Lubsza	Ri	Biecz	VT84	51°49’23”	14°51’27”
51	-	Bo	Osiek	VT94	51°49’32”	14°53’27”
52	-	Po-t	Biecz	VT83/93	51°48’15”	14°51’09”
53	-	Bo	Biecz	VT93	51°47’59”	14°51’48”
54	-	Bo	Biecz	VT93	51°47’24”	14°51’35”
55	-	Bo	Tarnów	VT93	51°47’25”	14°51’36”
56	Pstrąg	Ri	Tarnów	VT93	51°47’10”	14°50’30”
57	Tymnica	Ri	Tarnów	VT93	51°47’07”	14°51’34”
58	-	Bo	Tarnów	VT93	51°47’02”	14°52’28”
59	-	Bo	Tarnów	VT93	51°46’57”	14°52’41”
60	Tymnica	Ri	Tarnów	VT93	51°48’59”	14°53’00”
61	-	Sw-f	Chełm Żarski	VT93	51°46’37”	14°53’39”
62	-	Po-t	Chełm Żarski	VT93	51°41’55”	14°43’04”
63	-	Bo	Chełm Żarski	VT93	51°46’46”	14°54’46”
64	-	Bo	Chełm Żarski	VT93	51°46’33”	14°54’56”
65	-	Di	Nowa Rola	VT93	51°45’19”	14°54’28”
66	-	St	Dłużek	VT93	51°46’07”	14°55’36”
67	-	Sw-f	Nowa Rola	VT93	51°46’08”	14°55’31”
68	-	Po-p	Nowa Rola	VT93	51°45’18”	14°55’30”
69	-	St	Nowa Rola	VT93	51°44’49”	14°54’12”
70	Tymnica	Ri	Nowa Rola	VT93	51°43’50”	14°53’20”

RESULTS

Faunistic analysis

In total, 115 species from 10 families (Dytiscidae: 64 species, Hydrophilidae: 22, Haliplidae: 12, Helophoridae: 7, Gyrinidae: 3, Noteridae: 2, Hydraenidae: 2, Dryopidae: 1, Elmidae: 1, and Chrysomelidae: 1) were found in the investigated area (Tab. 2).

The most widespread species was *Hyphydrus ovatus* which occurred in 34.3% of all sites (Tab. 2). Additionally, 8 other species (*Hydrobius fuscipennis*,

Tab. 2. Aquatic beetle species recorded in the study area in the year 2011. Habitat types: ditches (Di), streams (St), rivers (Ri), small water bodies in open landscape (Sw-o) and in forests (Sw-f), temporary (Po-t) and permanent (Po-p) ponds, lakes (La), bogs (Bo) and marshes (Ma). Σ: sum of specimens collected. F_i – frequency index. Remarks: P – species protected by Polish law, N2000 – species listed in Habitat Directive, LC-CR – species from the Red List (CR – critically endangered, EN – endangered, VU – vulnerable, NT – near threatened, LC – least concern); *** – very rare species in Poland, ** – rare species, * – local species, # – first record in the Wielkopolsko-Kujawska Lowland.

No.	Species	Study sites	Habitat distribution (number of specimens)										Σ	F_i	Remarks
			Di	St	Ri	Sw-o	Sw-f	Po-t	Po-p	La	Bo	Ma			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Gyrinidae															
1.	*Gyrinus aeratus* Steph.	5,47,52,57,60			44	2		1					47	7.1	
2.	*G. paykulli* Ochs	28,52			1			1					2	2.9	
3.	*G. substriatus* Steph.	1,2,4,5,7,10,19,25,28,47,52,57	6		75	18		1		1			101	17.1	
Haliplidae															
4.	*Haliplus confinis* Steph.	52						1					1	1.4	
5.	*H. flavicollis* Sturm	13,15,34,41,43,47,52,68				1		15	13	3		1	33	11.4	
6.	*H. fluviatilis* Aubé	8,10,15,32-34,43,47,52,61,63			7	7	1	6	1		1	1	24	15.7	
7.	*H. fulvus* (Fabr.)	52							1				1	1.4	**
8.	*H. heydeni* Wehncke	15						1				2	2	1.4	
9.	*H. immaculatus* Gerh.	17						2					1	1.4	**
10.	*H. laminatus* (Schall.)	35,41											2	2.9	
11.	*H. lineatocollis* (Marsh.)	15										1	1	1.4	
12.	*H. ruficollis* (De G.)	2				2							2	1.4	
13.	*H. sibiricus* Motsch.	6,43,62				1		6					7	4.3	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
14.	*H. variegatus* Sturm	42,61					2				1		3	2.9	NT,**
15.	*H. varius* Nic.	68							2				2	1.4	EN, #
Noteridae															
16.	*Noterus clavicornis* (De G.)	14,35,41,43,52,62,68						32	6				38	10.0	
17.	*N. crassicornis* (O.F. Müll.)	3,4,12,14-16,21,29,32,41,43,44,52, 53,58,61-63,68	20		1	27	3	50	13	1	16	12	143	27.1	
Dytiscidae															
18.	*Agabus bipustulatus* (L.)	15,20,24,32,38,49,68				1	2		2		3	1	9	10.0	
19.	*A. didymus* (Olivier)	27,32,46				3				1			4	4.3	
20.	*A. fuscipennis* (Payk.)	22,45				2					1		3	2.9	
21.	*A. melanarius* Aubé	45				1							1	1.4	
22.	*A. paludosus* (Fabr.)	16,20,22,27,32,44	1			1			1	2	3		8	8.6	
23.	*A. uliginosus* (L.)	24-26,69		2						5	1		8	5.7	
24.	*A. undulatus* (Schrank)	3,20,32,41,43-45,48,52,62,63,68	2			2	1	6	4		1		16	17.1	
25.	*Ilybius ater* (DeG.)	14,20,21,32,34,40,45,48,51,52, 55, 63,64				3	1	8	11		24		47	18.6	
26.	*I. fenestratus* (Fabr.)	15,41,43,47,51,63,68				2		6	17		3	1	29	10.0	
27.	*I. fuliginosus* (Fabr.)	5,8,9,15,34,37,44,47,50,53,56,58	1		22	1			2		1	1	28	17.1	
28.	*I. quadriguttatus* (Lacord.)	12,18,20,43,48,50,51,52,63	1	1	2		9	2	4		3		22	12.9	
29.	*I. similis* Thoms.	20,43,58		1				1	2				4	4.3	
30.	*I. subaeneus* Er.	67					1						1	1.4	
31.	*Platambus maculatus* (L.)	7,12,49,50	4	4			1						9	5.7	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
32.	*Colymbetes fuscus* (L.)	5,17,32,37,38,40,41,43,44,47,51, 52,55	1		3	3		19			122		148	18.6	
33.	*C. paykulli* Er.	55									4		4	1.4	
34.	*C. striatus* (L.)	27,40,44,51,52,55,65,68	6					6	1	1	20		34	11.4	
35.	*Rhantus bistriatus* (Bergstr.)	21,29					1				1		2	2.9	
36.	*R. frontalis* (Marsh.)	21,24,32,41,44	3			7		1			3		14	7.1	
37.	*R. incognitus* R. Scholz	62						1					1	1.4	EN, ***
38.	*R. latitans* Sharp	14,20,43,47,62,68				1		5	8				14	8.6	
39.	*R. notatus* (Fabr.)	48					1						1	1.4	
40.	*R. suturalis* (MacL.)	3,10,16,20-22,24,40-43,47,51,52, 55,68			5	1		10	3	1	16		36	22.9	
41.	*R. suturellus* (Harr.)	45				2							2	1.4	
42.	*Liopterus haemorrhoidalis* (Fabr.)	15,24,43,62						2			1	1	4	5.7	
43.	*Acilius canaliculatus* (Nic.)	5,11,15,21,23,37,38,40,44,49,51, 52,55,68	2		5		4	2	1		142	2	158	20.0	
44.	*A. sulcatus* (L.)	5,32,37,40,44,48,51,52,55	5		1	1	1	5			190		203	12.9	
45.	*Graphoderus austriacus* (Sturm)	16,20,27,29,32,42-46,53,55,62				3	1	8	2	4	219		237	17.1	**
46.	*G. bilineatus* (De G.)	62						4					4	1.4	P, N2000
47.	*G. cinereus* (L.)	15,40,43,51,52,55,62						9			293	1	303	10.0	
48.	*Cybister lateralimarginalis* (De G.)	14,16,20,27,31,39,40,43,51,52, 55, 62,64,68						20	39	2	24		83	20.0	
49.	*Dytiscus circumcinctus* (Ahr.)	2,10,20,23,25,40,52,55			1	1		1	7	2	11	1	24	11.4	
50.	*D. circumflexus* Fabr.	40,55									13		13	2.9	
51.	*D. dimidiatus* Bergstr.	4,7,20,21,39,40,42,51-53,55,59,64			2			1	11		57		71	25.7	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
52.	*D. marginalis* L.	3,4,17,19,20,25,26,29,32,39,40, 42,51,52,54,55,62,68	1	1	3	1	1	12	7	1	49		76	25.7	
53.	*D. semisulcatus* (O. F. Müll.)	17,20						1	1				2	2.9	**
54.	*Hydaticus continentalis* Balfour-Browne	21,40,51,55									31		31	5.7	
55.	*H. seminiger* (DeG.)	12,15,16,21,22,24,26,27,32,40, 43, 44,51,53,55,64	2	1		1		1		7	134	1	147	22.9	
56.	*H. transversalis* (Pont.)	8,10,15,20,40,49,51,55			6		1		1		25	2	36	11.4	
57.	*Hydroglyphus geminus* (Fabr.)	6,7,29,32,36,40,52			1	12	1	12			1		28	10.0	
58.	*Graptodytes granularis* (L.)	20							1				1	1.4	
59.	*G. pictus* (Fabr.)	43,63						1			1		2	2.9	
60.	*Hydroporus angustatus* Sturm	3,6,11,24,32,38,46,50,58,63			1	5	1		1		4		12	14.3	
61.	*H. erytrocephalus* (L.)	2,3,21,24,32,42,46,58,63				5			1		7		13	12.9	
62.	*H. gyllenhalii* Schiödte	24,27								1	3		4	2.9	VU
63.	*H. incognitus* Sharp	20,24,32,44,46,59	3			3			3		5		14	8.6	#
64.	*H. melanarius* Sturm	58									1		1	1.4	
65.	*H. memnonius* Nic.	16,24								1	1		2	2.9	#
66.	*H. obscurus* Sturm	22,24,52,63						1			4		5	5.7	
67.	*H. palustris* (L.)	4,11,15,19,20,24,27,32,43,44, 49,62	3		1	1	2	2	5	1	1	3	19	17.1	
68.	*H. rufifrons* (Duftschm.)	15,21,43,44,58	1					1			2	1	5	7.1	
69.	*H. scalesianus* Steph.	58									1		1	1.4	
70.	*H. striola* (Gyll.)	39,49					4		2				6	2.9	
71.	*Porhydrus lineatus* (Fabr.)	47				1							1	1.4	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
72.	*Scarodytes halensis* (Fabr.)	50			1								1	1.4	
73.	*Suphrodytes dorsalis* (Fabr.)	21,24,42,44,64	2				2				7		11	7.1	
74.	*Hydrovatus cuspidatus* (Kunze)	14							2				2	1.4	**
75.	*Hygrotus impressopunctatus* (Schall.)	20,21,24,29,32,34,39,40,42,43 ,52, 68				6	1	4	5		15		31	15.7	
76.	*H. inaequalis* (Fabr.)	4,6,15,17,32,40,48,61			1	2	3	3			1	1	11	11.4	
77.	*Hyphydrus ovatus* (L.)	4,5,8,10,14,15,19,20,26 ,29,32,35, 40,41,43,44,46-49,62,64,65, 68	7	2	12	6	3	39	22		5	8	104	34.3	
78.	*Laccornis oblongus* (Steph.)	3,17,52						2	1				3	4.3	*
79.	*Laccophilus hyalinus* (De G.)	4,15,29,30,40,45,47,52,68			7	3	1	14	1		2	2	30	12.9	
80.	*L. minutus* (L.)	47,62				1		1					2	2.9	
81.	*L. poecilus* Klug	25,27,32,40,43,62,68				1		5	1	2	6		15	10.0	*
Helophoridae															
82.	*Helophorus aquaticus* (L.)	32,44	1			1							2	2.9	
84.	*H. flavipes* Fabr.	8,65	1		1								2	2.9	
84.	*H. granularis* (L.)	21,32,43,47,50,52			1	2		5			4		12	8.6	
85.	*H. griseus* Herbst	6,8,9,15,29,32,37-39,52,68			3	38	1	5	5		1	1	54	15.7	
86.	*H. minutus* Fabr.	68							1				1	1.4	
87.	*H. nubilus* Fabr.	8,32			1	4							5	2.9	
88.	*H. pumilio* Er.	7			2								2	1.4	**
Hydrophilidae															
89.	*Anacaena limbata* (Fabr.)	3,8,11,19,20,23-25,32,34,39,44,46, 58,65	7		1	16	1		14	1	7	3	51	21.4	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
90.	*A. lutescens* (Steph.)	4,6,11,15,38,66		1	1	3	4				1	2	12	8.6	
91.	*Berosus signaticollis* (Charp.)	19	1										1	1.4	*
92.	*Cymbiodyta marginella* (Fabr.)	4,42			1						1		2	2.9	
93.	*Enochrus affinis* (Thunb.)	6,29,32,38,39,44,45,47,52	1			10	1	1	1		5		19	2.9	
94.	*E. bicolor* (Fabr.)	6,9,12	2		1	1							4	4.3	EN, *
95.	*E. coarctatus* (Gredl.)	6,10,29,32,44,50,52,58,64	4		3	48	2	5			2		64	12.9	
96.	*E. melanocephalus* (Oliv.)	5,6,8,12,15,44,45 ,58,64	2		5	2					2	1	12	12.9	*
97.	*E. ochropterus* (Marsh.)	3,24,27,29,32,44,52,58	1			2	5	1	1	1	2		13	8.6	
98.	*E. quadripunctatus* (Herbst)	6,14,32-34,43-45,52,62	3			45		31	1				80	14.3	
99.	*E. testaceus* (Fabr.)	17,20,27,35,68						3	3	2			8	7.1	
100.	*Helochares obscurus* (O. F. Müll.)	3,6,9,11,12,15,17,20,22,29,32,34, 38,40,42,44,52,62,68	14		1	13	5	5	13		11	1	71	27.1	
101.	*Hydrobius fuscipes* (L.)	3,6,8,10,12,13,16,23,29,32,34,36, 37,39,40,43-45,47,52,62	4		5	67	3	32	6	4	1	2	124	30.0	
102.	*Hydrochara caraboides* (L.)	3,8,13,17,22,32,37,40,41,43,44,47,52,62	1		1	3		7	6	3	2		23	20.0	
103.	*Hydrophilus aterrimus* Eschsch.	14,15,16,20,41,43,52,61,62					1	12	1	1		3	18	12.9	P, VU, *
104.	*H. piceus* (L.)	14,16,20,43,62						6	1	4			11	7.1	P, NT
105.	*Laccobius bipunctatus* (Fabr.)	34							1				1	1.4	**
106.	*L. minutus* (L.)	8,15,23,24,34,36,52			1			7	1		1	2	12	10.0	
107	*Coelostoma orbiculare* (Fabr.)	9,12,27,43	7		1			1			1		10	4.3	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
108.	*Cercyon bifenestratus* Küst.	6,9,39,48,52			3	11	1	1	4				20	7.1	
109.	*C. marinus* Thoms.	9,39,49			4		1		19				24	4.3	
110.	*C. tristis* (Ill.)	12	1										1	1.4	LC
	Hydraenidae														
111.	*Limnebius parvulus* (Herbst)	6,37				1		1					2	2.9	
112.	*Ochthebius minimus* (Fabr.)	63									1		1	1.4	
	Elmidae														
113.	*Limnius volcmari* (Panz.)	70			1								1	1.4	
	Dryopidae														
114.	*Dryops griseus* (Er.)	42									1		1	1.4	
	Chrysomelidae														
115.	*Macroplea appendiculata* (Panz.)	52						1					1	1.4	P, CR, ***, #

Helochares obscurus, *Noterus crassicornis*, *Dytiscus dimidiatus*, *D. marginalis*, *Hydaticus seminiger*, *Rhantus suturellus*, *Anacaena limbata*) occurred in more than 20% of all sites. In contrast, 54 species were recorded at less than 5% of sites, including 29 species that were present at only one site. Within this group, a high number of habitat specialists was present: tyrphophiles (11 species), rheophiles (3), limnephiles (2), tyrphobionts (1), hylophiles (1), argilophiles (1), and halophiles (1).

Within habitats, the most species-rich were permanent ponds and bogs, based on median values (Fig. 2). However, the highest number of species was found at site No. 52 (a temporary pond) and at site No. 32 (a small water body in an open landscape) with 44 and 42 species, respectively (Tab. 2). In other habitat types the maximum number of species per site was much lower: in ditches, permanent ponds, bogs and marshes, 20–30 species were found, whereas in rivers, small water bodies in forests and lakes 10–20 species occurred (Fig. 2). The lowest species number was found in streams (maximum of 4 species per site).

Related to environmental preferences of species, the most species-diverse habitat types were temporary ponds (Fig. 3), where 7 groups of specialists were found. Nevertheless, in other habitat types, with the exception of streams, high diversity of specialist groups was observed (5–6 groups for each habitat type). The two most species-rich classes, eurytopes and tyrphophiles, were present in every habitat type. The hylophiles were also widespread among almost all habitat types, with exception of small water bodies in open landscape. Most rheophiles were observed in rivers, but not in streams.

Protected, endangered and rare species

In total, 10 species protected by law or/and listed in the Polish Red List, with additional 11 species that are rare and local, as well as 4 new species for the faunistic region were found in the study area (Tab. 2). Among 7 species of aquatic beetles protected by law, 4 (*Macroplea appendiculata, Graphoderus bilineatus, Hydrophilus aterrimus, H. piceus*) occurred in the investigated area. Among Red List species, special attention should be paid to *M. appendiculata* – a critically endangered (CR) species and protected by law, which has already been mentioned above. Further, according to the Red List, 3 species (*Enochrus bicolor, Haliplus varius, Rhantus incognitus*) are classified as endangered (EN), 2 species (*H. aterrimus, Hydroporus gyllenhalii*) as vulnerable (VU), 2 species (*Haliplus variegatus*, *H. piceus*) as near threatened (NT), and 1 species (*Cercyon tristis*) as least concern (LC). Two of the collected species are very rare in Poland (*Rhantus incognitus* and *Macroplea appendiculata*), 8 are rare (*Haliplus fulvus*, *H. immaculatus*, *H. variegatus*, *Graphoderus austriacus*, *Dytiscus semisulcatus*, *Hydrovatus cuspidatus*, *Laccobius bipunctatus* and *Helophorus pumilio*), and 6

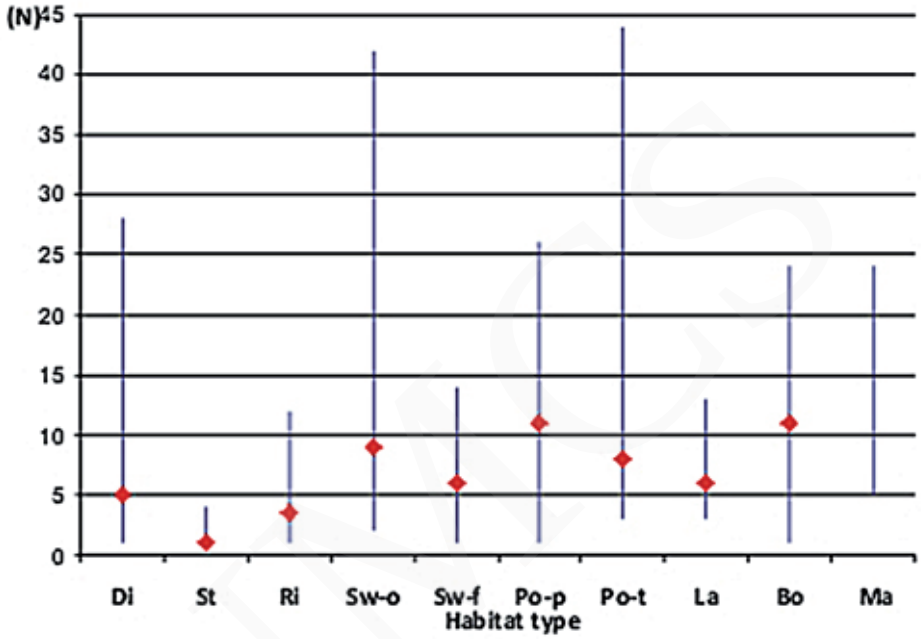

Fig. 2. Number of species (N) recorded in sites representing different habitat types (ranges and median values): ditches (Di), streams (St), rivers (Ri), small water bodies in open landscape (Sw-o) and in forests (Sw-f), temporary (Po-t) and permanent (Po-p) ponds, lakes (La), bogs (Bo) and marshes (Ma). Note that for marshes there is no median value, since there were only 2 study sites.

are local (*Berosus signaticollis*, *Enochrus bicolor*, *E. melanocephalus*, *Laccornis oblongus*, *Laccophilus poecilus* and *Hydrophilus aterrimus*). Details (date, number of individuals and habitat descriptions) of the species mentioned above are given in Table 3.

Protected, endangered and rare species taken into the evaluation of habitats occurred at 30 study sites (43%) in almost all habitat types, with exception of streams. The evaluated sites received from 1 to 16 points, with 3 sites receiving more than 10 points; 6 sites – 6–10 points; and 21 sites 1–5 points. The site No. 62 (Chełm Żarski, Po-t) was the most valuable habitat with 16 points. Sites No. 20 (Ruskie Stawy, Po-p) and 52 (Biecz, Po-t) each received 11 points (Tab. 4). Among the evaluated habitat types, the most numerous (5 sites each) were temporary and permanent ponds. Rivers, small waters in open landscape and bogs each had 4 evaluated habitats. Lastly, ditches (3 sites), lakes (2), small waters in forests (2) and marshes (1) were used in the analysis (Tab. 4).

Summarised values for each habitat type showed that the temporary and permanent ponds were the most valuable habitats for rare, endangered and/or protected species, with 45 and 28 points, respectively (Fig. 4). Other habitat types

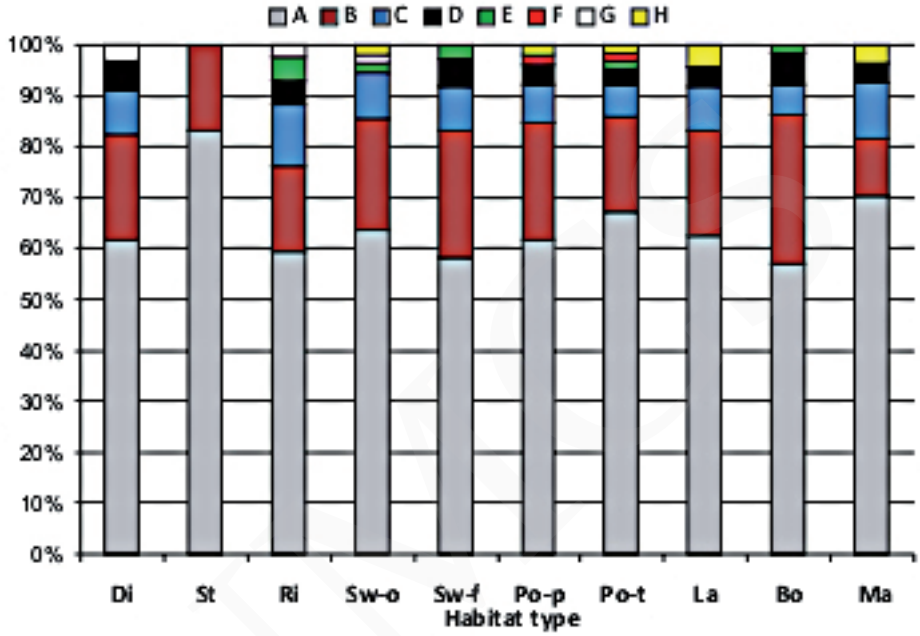

Fig. 3. Relative composition (%) of specialists based on species number in particular habitat types (symbols of the habitats like in. Tab. 1 and Fig. 2). A – eurytopes, B – tyrphophiles and tyrphobionts, C – rheophiles, D – hylophiles, E – argilophiles, F – limnephiles, G – halophiles, H – psammophiles.

received considerably lower values (4–15 points). On average, the most valuable habitat types were temporary ponds (9 points). Further, lakes (7.5), permanent ponds (5.6), and small waters in forests (4.5) all had moderately high values (Fig. 4).

The spatial distribution of these important sites followed two distinct patterns in the study area: 1) highly- and moderately-valuable sites (>5 points) were situated in forested and not in agriculturally managed parts of the landscape and generally represented larger standing waters (ponds and lakes); 2) sites with < 5 points were widely spread in the whole study area, however they represented mostly bogs and small waters in the forest-dominated part, and small waters and rivers in the agriculture-dominated part (Fig. 5).

DISCUSSION

The presented data, besides providing a description of aquatic beetles in a previously non-investigated area, are of high interest because they provide evi-

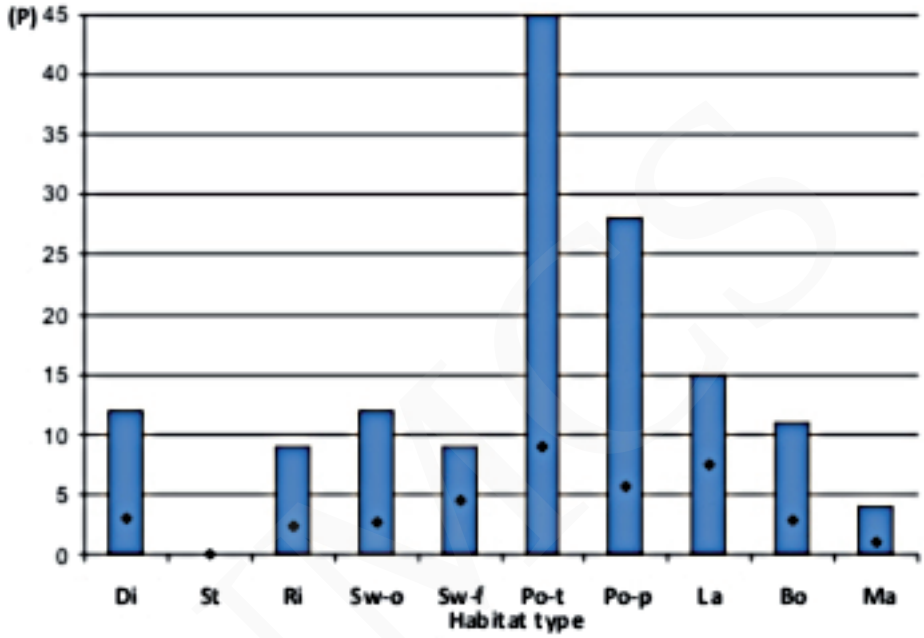

Fig. 4. Importance of particular habitat types (P) based on sums (columns) and means (black dots) of the point system assigned based on numbers of endangered, protected and rare species (symbols of the habitat types like in Tab. 1).

dence of high species richness, new records of rare species in Poland (6) and in the faunistic region Wielkopolsko-Kujawska Lowland (26, 27), data concerning habitat preferences, and zoogeographical distribution aspects of particular species.

Only four species were recorded as new to the Wielkopolsko-Kujawska Lowland. However, certain areas of the Wielkopolsko-Kujawska Lowland are part of one of the most investigated faunistic regions of Poland, though these highly-researched areas did not include areas investigated in our study. Particularly rich are historical data (26, 27, 47). Later on, few systematic but many localized, short-term studies were carried out, which can be seen in an impressively long list of publications with original data (5, 25, 28, 46, 48, 59, 68, 69, 71, 72, 73, 77, 79, 85, 86, 87, 88, 89, 90, 92, 93, 94, 95, 96, 98, 99, 100, 101, 106, 107, 110, 112, 118). Overall, ca. 230 species of "true water beetles" have been recorded in the Wielkopolsko-Kujawska Lowland so far. The 4 new species from this study are: *Haliplus varius*, *Hydroporus incognitus*, *H. memnonius* and *Macroplea appendiculata*. Among them, only *M. appendiculata* is very rare on the national scale (6). The lack of recent information from the investigated area about the occurrence of *Hydroporus incognitus*, a tyrphophilous species regularly recorded from

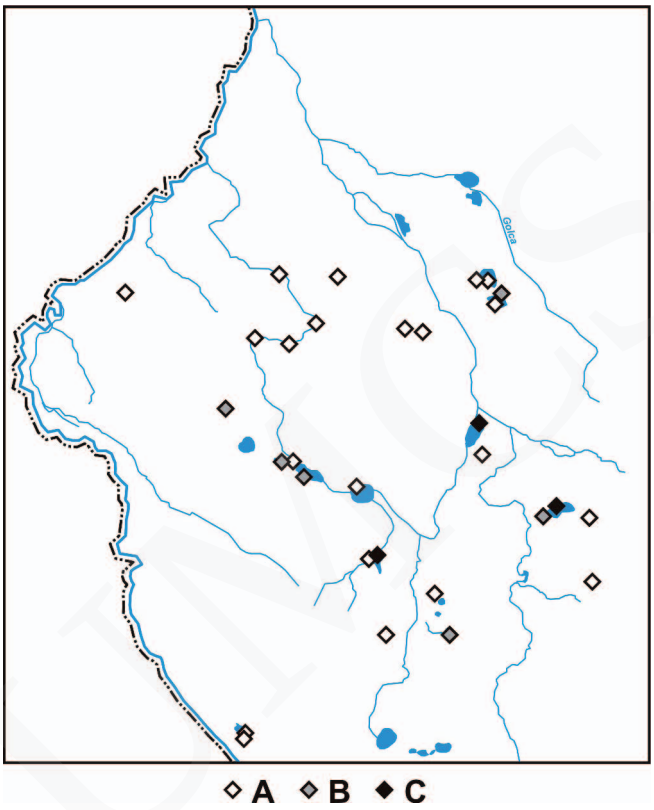

Fig. 5. Spatial distribution of sites found as the most important for endangered, protected and rare species. A – 1–5 points, B – 6–10 points, C – over 10 points.

neighbouring faunistic regions of Poland (3, 4, 12, 14, 17, 26, 58, 77, 80, 83, 119) and from Germany (33, 36, 67, 113), is noteworthy. This clearly indicates gaps in the knowledge about the distribution of some rare species in the Wielkopolsko-Kujawska Lowland and confirms an urgent need for further systematic studies in this region.

Only *Suphrodytes dorsalis* (Fabr.) was found as a representative of the genus *Suphrodytes* Goz. This is important information in the light of the genetically confirmed data about existence of two different *Suphrodytes* species in Europe. The second species is *Suphrodytes figuratus* (Gyll.), which was earlier synonymised with *S. dorsalis*. Some authors regarded it as a colour variant of *S. dorsalis* (120). Now *S. figuratus* is regarded as a distinct species (2, 35). It has been already shown in Great Britain, both species are widely distributed and often co-occur (35). Furthermore, *Suphrodytes figuratus* has already been discovered in Poland, in the Wieprz Valley in Lublin Province (23). From this point of view, existing

Tab. 3. Detailed information on the protected, endangered and rare species (alphabetically) in the study area. N – number of individuals.

Species	Site no.	Date	N	Habitat description
Berosus signaticollis	19	17.04.2011	1	eutrophic pond strongly overgrown with helophytes and hydrophytes
Cercyon tristis	12	05.08.2011	1	highly eutrophic ditch water, with muddy sediments and strongly sun exposure
Graphoderus austriacus	16	24.05.2011	3	predominantly in small water bodies with rich vegetation or in small *Sphagnum* bogs, occasionally in bigger waters that are mainly eutrophic, shallow, and vegetation-rich lakes and ponds
	20	01.06.2011	2	
	27	01.06.2011	1	
	29	21.04.2011	1	
	32	03.06.2011	1	
	42	18.05.2011	1	
	43	04.06.2011	2	
	45	11.05.2011	2	
	46	19.05.2011	1	
	53	24.05.2011	1	
	55	14.07.2011	217	
	62	25.05.2011	6	
Graphoderus bilineatus	62	25.05.2011	4	sun-exposed shore area (ca. 0.5–1 m deep) of a eutrophic fish pond overgrown with helophytes dominated by *Glyceria maxima* (Hartm.) Holmb. and *Phragmites australis* (Cav.) Trin. ex Steud and hydrophytes dominated by *Nymphaea alba* L.
Dytiscus semisulcatus	17	09.08.2011	1	sun-exposed sites in ponds strongly overgrown with helophytes and hydrophytes and low water level
	20	17.04.2011	1	
Enochrus bicolor	6	13.07.2011	1	highly eutrophic sun-exposed habitats, with low water levels and muddy sediments
	9	04.08.2011	2	
	12	05.08.2011	1	
Enochrus melanocephalus	5	17.07.2011	1	various habitats with small water areas (small waters, small slow running rivers, marshes, ditches, bogs), with shallow and vegetation rich shores, mainly in sun-exposed sites
	6	13.07.2011	1	
	8	17.07.2011	4	
	12	05.08.2011	1	
	15	04.08.2011	1	
	44	04.06.2011	1	
	45	11.05.2011	1	
	58	24.05.2011	1	
	64	11.04.2011	1	

Haliplus fulvus	52	17.04.2011	1	sun-exposed eutrophic pond in an area strongly overgrown with helophytes and low water level
Haliplus immaculatus	17	28.04.2011	1	shore area of a eutrophic fishpond sparely overgrown with helophytes, predominantly with *Phragmites australis*
Haliplus variegatus	42	18.05.2011	1	flat, slightly dystrophic waters overgrown with *Phragmites australis*, *Carex* spp. and *Sphagnum* spp., and surrounded by pine forests
	61	11.04.2011	2	
Haliplus varius	68	13.06.2011	2	eutrophic, permanent pond, well developed and species rich helo- and hydrophytes, heavily shaded by trees
Helophorus pumilio	7	17.07.2011	2	slowly running river, with shores overgrown by grasses and bottom covered by hydrophytes
Hydrophilus aterrimus	14	26.05.2011	1	associated with eutrophic, flat and extended waters (ponds and lakes) strongly overgrown with helo- and hydrophytes
	15	05.08.2011	3	
	16	24.05.2011	1	
	20	01.06.2011	3	
	41	04.06.2011	3	
	43	04.06.2011	3	
	52	04.06.2011	2	
	61	25.05.2011	1	
	62	25.05.2011	1	
Hydrophilus piceus	14	26.05.2011	1	associated with eutrophic, flat and extended waters strongly overgrown with helophytes and hydrophytes, co-occurs with *H. aterrimus* at many sites
	16	24.05.2011	4	
	20	01.06.2011	1	
	43	04.06.2011	4	
	62	25.05.2011	1	
Hydroporus gyllenhalii	24	01.06.2011	3	shore area of a eutrophic lake, overgrown with *Phragmites australis* with low water level and muddy sediments, strongly shaded by *Alnus glutinosa* (L.) Gaertn.
	27	18.04.2011	1	*Sphagnum* mats of a dystrophic transitional bog
Hydroporus incognitus	20	01.06.2011	3	diverse habitats types small water bodies in open landscapes, bogs, ditches, and ponds; all sites rich in helo- and hydropytes, rather eutrophic with shallow water, but different exposure to the sun
	24	18.04.2011	2	
	32	03.06.2011	1	
	44	18.05.2011	3	
	46	19.05.2011	2	
	59	04.05.2011	3	

Hydroporus memnonius	16	24.05.2011	1	dystrophic peat bog within a forested area, in *Sphagnum*-mats
	24	01.06.2011	1	marsh muddy sediments among a shoreline of a eutrophic lake, strongly shaded by trees
Hydrovatus cuspidatus	14	26.05.2011	2	small eutrophic pond strongly overgrown with helophytes and hydrophytes
Laccobius bipunctatus	34	03.06.2011	1	shallow shore area of a eutrophic permanent fish pond, sparsely covered with helophytes (e.g. *Carex* sp., *Juncus* sp., *Schoenoplectus lacustris* (L.) Palla, and *Phragmites australis*)
Laccophilus poecilus	25	26.05.2011	1	broad spectrum of standing waters, caught in small water bodies, ponds and lakes
	27	18.04.2011	1	
	32	27.04.2011	1	
	40	19.06.2011	6	
	43	04.06.2011	2	
	62	25.05.2011	4	
	68	13.06.2011	1	
Laccornis oblongus	3	06.05.2011	1	permanent eutrophic ponds strongly overgrown with helophytes and hydrophytes
	17	28.04.2011	1	
	52	15.07.2011	1	
Macroplea appendiculata	52	15.07.2011	1	fish pond complex, in a currently non-used pool containing only seasonally shallow water (maximal 50 cm depth) overflowing from the main pool, with dense vegetation of hydrophytes (mainly *Potamogeton pusillus* L. and *P. pectinatus* L.), strongly sunny site
Rhantus incognitus	62	25.05.2011	1	sun-exposed shore area (ca. 0.5–1 m deep) of a eutrophic fish pond overgrown with helophytes dominated by *Glyceria maxima* and hydrophytes dominated by *Nymphaea alba*

evidence has to be verified as it cannot be excluded that some data given about *S. dorsalis* may actually correspond to *S. figuratus*.

So far, ca. 350 species of "true water beetles" have been found in Poland. However, the total number of representatives of investigated families is much bigger, as some species from Hydrophiloidea are terrestrial, inhabiting e.g. animals' faeces (6). Thus, 115 species found in the investigated area comprise approximately one third of the Polish fauna of aquatic beetles. Taking the limits of selected habitats and only one season of systematic investigation into consideration, this represents a high number of species for the area. In general, similar or lower numbers of species are the result of long-term studies on extended and highly

Tab. 4. Ranking of the most valuable sites based on point system (P): the sum of points attributed to endangered, protected, and rare species found per each study site. Di – ditch, St – tream, Ri – river, Sw-o – small water body in open landscape, Sw-f – small water body in forest, Po-p – permanent pond, Po-t – temporary pond, Bo – bog, Ma – marsh.

(P)	Site no. (habitat type)
16	62 (Po-t)
11	20 (Po-p), 52 (Po-t)
10	14 (Po-p)
9	16 (La), 43 (Po-t)
8	12 (Di)
7	61 (Sw-f)
6	27 (La)
5	17 (Po-t), 42 (Bo)
4	6 (Sw-o), 9 (Ri), 15 (Ma), 24 (Bo), 41 (Po-t), 68 (Po-p)
3	44 (Di), 45 (Sw-o)
2	5 (Ri), 7 (Ri), 29 (Sw-f), 32 (Sw-o), 34 (Po-p), 46 (Sw-o)
1	3 (Po-p), 8 (Ri), 19 (Di), 54 (Bo), 64 (Bo)

valuable regions in central and mid-eastern parts of Europe (1, 4, 5, 15, 16, 19, 20, 21, 29, 36, 50, 64, 74, 75, 82). Our results indicate a considerable high species richness of aquatic beetles in the area and further its important role in biodiversity preservation on the national scale as well as in Central Europe. Moreover, the qualitatively rich fauna of aquatic beetles indirectly reflects highly heterogeneous, good quality freshwaters and low anthropogenic impact (34, 49, 56, 102, 109, 115). The diversity of aquatic beetles might be only moderately distinguished by eurytopic species (ca. 100 species in Poland), as stenotopic ones may significantly increase the total number of this insect group. Therefore, the condition *sine qua non* of species richness is habitat diversity, ensuring suitable conditions for the development of stenotopic species (6).

Considering the lack of knowledge about the distribution patterns for many species in Poland, the evaluation of rare and locally occurring taxa, including the Red List, is usually based on analysis between historical and contemporary data (6, 84), thus possibly containing flawed information in regard to species composition and their state of threat (17). Nevertheless, the Red List is the only source that compiles the entire fauna of Poland, thus allowing to evaluate species on the national level. In the study area, the occurrence of many species present in the Red List, especially highly threatened: *Haliplus varius*, *Rhantus incognitus*, *Hydroporus gyllenhalii*, *Enochrus bicolor*, *Hydrophilus aterrimus* and *Macroplea*

appendiculata (84) as well as 57% of protected aquatic beetles (104) provides evidence that it is an area of high-quality habitat. Further, comparing the data from this study to Red Lists from neighbouring areas provides an objective indicator of the considerable importance of this area for the preservation of aquatic beetle diversity. For example, we found 29 species from the Red List of Germany, among them 22 species highly threatened (45). Similar results gives the review of German's regional Red Lists from: Mecklenburg-Vorpommern (55), Brandenburg (8) and Saxony (61). Further, 25 species (18 highly threatened) found in this study are present on the Red List of the Czech Republic (32). Four species listed on the all mentioned Red Lists (*Haliplus variegatus*, *H. varius*, *Hydrophilus aterrimus* and *H. piceus*) overlapped with the ones on Poland's Red List. Furthermore, from the recorded species, the most endangered species in particular countries were *Haliplus fulvus*, *H. variegatus*, *H. varius*, *Agabus fuscipennis*, *Rhantus suturellus*, *Cybister lateralimarginalis*, *Dytiscus semisulcatus*, *Hydroporus rufifrons*, *H. scalesianus*, *Hydrovatus cuspidatus*, *Laccornis oblongus*, *Laccophilus poecilus*, *Hydrophilus aterrimus*, *H. piceus*, *Dryops griseus* and *Macroplea appendiculata* (8, 32, 45, 55, 61). Consequently, the south-west part of the Lubuskie Province should be seen as an important refugium for aquatic beetles in Central Europe.

Regarding ecological preferences among species rarely and locally recorded in Poland (6), several groups could be distinguished. The biggest group was formed by eurytopic species, widely distributed in the area with some preferences to dystrophic waters, which also may occur in sustainable eutrophic biotopes, however, they are threatened due to continuous eutrophication of waters (84). The typical examples were: *Haliplus fulvus*, *H. immaculatus*, *H. variegatus*, *Graphoderus austriacus*, *Dytiscus semisulcatus*, *Laccobius bipunctatus*, *Hydrophilus aterrimus* and *H. piceus* (26, 27, 43, 52, 53, 60, 78). The second most numerous group was formed by tyrphophiles, e.g. *Hydrovatus cuspidatus*, *Laccornis oblongus*, *Laccophilus poecilus*, *Helophorus pumilio*, *Berosus signaticollis* and *Enochrus melanocephalus* (30, 51, 84), which are endangered due to wide-spread habitat degradation. Further, some rheophiles (*Rhantus incognitus*), limnephiles (*Macroplea appendiculata*) and halophiles (*Enochrus bicolor*) (10, 108, 116), which occurred only locally and have limited dispersal capabilities also enhance the total diversity of aquatic beetles in the area.

Several species are interesting with regard to their zoogeographical distribution and/or environmental preferences. Below, we discuss the most interesting records.

Enochrus bicolor is widely distributed Palaearctic species (66), halophilous species associated with waters next to coasts or with high salinity. In Poland, this species is present in freshwaters in many regions. So far, *E. bicolor* was reported in 12 of 25 faunistic regions, often from different areas without any saline bio-

topes (17, 24, 58, 98, 108). The new data from the Lubuskie Province confirm this, indicating a high mobility potential of this species and/or high tolerance to considerable salinity fluctuations (47).

Rhantus incognitus is a Central European species with *locus typicus* in Poland (Susz *ad* Iława – 111). It is rheophilous species, favouring valleys of small and middle-sized rivers. Recently recorded from several sites located in the area from Latvia to north-eastern Poland and western Belarus to Slovakia and western Ukraine (10, 65, 81). Lately, *R. incognitus* has been found in western Poland (44, 94), eastern Germany and western Russia (31, 54). Moreover, recent records from the core of *R. incognitus*' range have been published (14, 22, 24, 54, 91, 92). These records indicate that the species has increased its frequency in its core range and expanded westwards, where it has been discovered in the areas heavily investigated for aquatic Coleoptera (54). The new record in Chełm Żarski might be seen as a link between the existing sites from western Poland and north-eastern Germany.

Macroplea appendiculata is a Western Palaearctic leaf beetle (Chrysomelidae) associated with shore areas of standing and slowly running waters with abundant hydrophytes (*Myriophyllum spicatum* Linnaeus, 1758 and/or *Potamogeton* spp.). Imagines live at the bottom, at high depths attached to the aquatic plants (116). In Poland, the historical records are 80-year-old and come from only several sites from 5 faunistic regions: Pomeranian Lake District, Mazovian Lowland, Lower and Upper Silesia, and Western Beskidy Mountains (26). Consequently, according to the Red List, the species is critically endangered (84). Until 2006, only two new records of *M. appendiculata* were reported from the Lublin Upland (113). Later on, the species was discovered in the Małopolska Upland (11) and rediscovered in Pomeranian Lake District (11, 13). Our data provides evidence that this species also occurs in the Wielkopolsko-Kujawska Lowland. Recent records suggest that *M. appendiculata* might be more frequent and widespread in Poland than expected. One of the explanations could be related strictly to sampling techniques used for aquatic beetles, which often do not cover deeper parts of the water shore areas (114). This has been confirmed during the river monitoring done with "Multi-Habitat Sampling" protocols, where *M. appendiculata* was found (11).

Our results show that the diversity of aquatic beetles, including species of special concern, is dispersed over few habitat types in the study area. Permanent ponds and bogs were the most species-rich habitats, on average. Despite this, the maximal species numbers per site were found in temporary ponds and in small water bodies in open landscapes. Additionally, the evaluation of habitat types showed clearly that extended standing waters, like temporary and permanent fish ponds, as well as lakes, are the most valuable biotopes for endangered, protected and rare species. Thus, the permanent and temporary fish ponds seem to be of the highest importance for conservation as they contain more than 65% of total spe-

cies number as well as more than 70% of protected, endangered and rare species found in the area. This contrasts partially with results of other investigated regions of Poland, where the highest species richness was found mostly in habitats of natural origin, like rivers (24) or fens and peat bogs (19). Nevertheless, fish ponds contained a high number of protected, rare and endangered species as well (9, 24). It can be assumed that these artificial water bodies play a key role for the distribution and species richness of aquatic beetles in lake-poor areas, especially in mid-western Poland. Moreover, since it is known that species diversity responds negatively to hypertrophic conditions in ponds (70), it can be stressed that our investigated habitats experience only moderate anthropogenic pressure related directly to the fish production, thus enhancing their importance for both fish management and nature conservation. It is noteworthy that a clear decrease in highly important habitats takes place between forested and agriculturally-dominated parts of the study area. It has already been shown that small static water bodies in fairly managed open landscape in agriculturally-dominated areas might be suitable habitats for a high diversity of aquatic beetles (15). However, in our study, the relatively small number of rare and endangered species in open landscapes compared to habitats in forested areas suggest a high anthropogenic pressure on small waters related to various agriculture activities.

We conclude that the investigated area is of high importance for aquatic beetles on both the regional and national scale, due to their high diversity, including protected, rare and threatened species, in addition to the new species found for the faunistic region. Our results provide evidence that permanent fish ponds and peat bogs contain the highest diversity, whereas large waters like permanent and temporary fish ponds play a key role for the high content of species of concern (protected, endangered and rare) in the lake-poor area.

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