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WATER BEETLES (COLEOPTERA) OF SMALL RESERVOIRS IN THE NEIGHBORHOOD OF ŚWINOUJŚCIE (NW POLAND)

Abstract

The present paper describes a diversity of water beetle communities inhabiting five small water reservoirs, located in the north-western part of Wolin Island, near of Świnoujście city (Poland). The analyzed aspects of beetle communities included differences in species composition and the abundance of beetles in various water bodies, taking into account such features of the reservoirs as their size, periodical character, maximum depth, structure of vegetation and the percentage of surface shaded by plant canopy. In total, 60 species of beetles were recorded in the reservoirs, including three species endangered with extinction in Poland, i.e. *Haliplus apicalis*, *H. furcatus*, *H. variegatus*, and one species critically endangered with extinction in Poland, namely *Spercheus emarginatus*. The largest number of species (42) and individuals (1294) was found in a periodical, relatively big, open and shallow pool situated in a lowland peat bog and covered with soft submerged vegetation. However, the population of beetles found in this location was strongly dominated by two species, *Hydrochara caraboides* and *Hygrotus decoratus*, which resulted in the lowest biodiversity coefficient (H` = 0.705) in comparison with the other investigated reservoirs. In permanent but significantly shaded reservoirs, the number of recorded species was almost two times lower and the abundance of beetles was even eight times lower. However, in such water bodies the diversity coefficient had the highest values (0.981 < H` > 0.991). As far as the

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environmental aspects were concerned, it was discovered that the most significant were the size of the reservoir and its permanent/non-permanent character. Only the differences in size reached the level of statistical validity ($p = 0.040$), explaining 34.8% of cases of species variability. The similarity among beetle communities inhabiting particular reservoirs varied from 31.63% to 53.3% and was connected with ecological similarity of the investigated water bodies.

Keywords: water beetles, threatened species, small water bodies, Wolin Island

Introduction

Small water bodies constitute interesting ecological systems characterized by a significant variability of environmental conditions and the presence of diversified habitats. Due to their common occurrence they are an important source of local biodiversities, increasing the heterogeneity of the ecological landscape by participating in the creation of a mosaic system of habitats which is beneficial to the environment. At the same time, such water bodies are vulnerable to degradation and endangered by disappearance (Collinson et al. 1995, Bosiacka & Pieńkowski 2004, Meester et al. 2005). Such small ecosystems may have enormous environmental significance, as they constitute refugia for a numerous group of valuable invertebrates, including water beetles, which are one of the most important elements of their zoocenoses (Collinson et al. 1995, Zawal et al. 2004). Assemblages of beetles have an unstable character and are subject to dynamic quantitative and qualitative changes reflecting the temporary habitat conditions, as well as the migration or adaptation potential of particular components of such communities. Especially with respect to ecosystems characterized by large variability, there is relatively little knowledge as to the mechanism of Coleoptera fauna dispersion. Such fauna typically represents a low degree of ecological specialization and a high degree of mobility. Due to the character of Coleoptera fauna, an important role in its distribution and colonization of particular water bodies is played by the randomness factor. However, it was observed in the past that beetles tended to choose their habitats selectively (Krach 1932, Ziemmerman 1959). A majority of studies investigating the relation between environmental features of small water bodies and the beetle assemblages encountered in them focused on the most typical morphological factors differentiating these biotopes, such as permanency, size, water surface exposure to light, depth and vegetation structure, listing all these factors as the most significant ones in shaping the variability of local beetle fauna (Foster et al. 1992, Nilsson & Svensson 1995, Collinson et al. 1995, Downie et al. 1997, Rundle et al. 2002, Cooper et al. 2005, Sanderson et al. 2005, Binkley & Resetarits, 2007). Less frequently analyzed was the importance of such factors as predation, spatial distribution of water bodies, type of substrates, or chosen physical and chemical parameters of water (Bosi 2001, Verbek et al. 2001, Rundle et al. 2002, Fairchild et al. 2003, Sanderson et al. 2005, Binkley & Resetarits 2005). Verberk et al. (2002) observed that in a heterogeneous system of large water and mud complexes the diversity of macrofauna was explicable by the influence of larger ecological entities, such as the elements of landscape, rather than by the vegetation structure, which might greatly vary in various locations. An important issue arising in connection with such studies as the ones described above is whether the obtained results have a universal character which would allow to create a general model of beetle dispersion in a dynamically changing water environment. Many of the studies describe very specific habitat types (e.g. water reservoirs in the forests of the subpolar zone) and vary with respect to the ecological scale and range of studied parameters (Foster et al. 1992, (Nilsson & Svensson 1995), Downie et al. 1997, Fairchild et al. 2003).

The present study was conducted in the area of Wolin Island, situated between the Szczecin Lagoon and the Baltic Sea (north-western Poland). The state of knowledge about the Coleoptera fauna of the region was unsatisfactory and based mainly on data provided by the studies of Podgórniak (1960), and Kornobis (1979). The most valuable, and at the same time most thoroughly studied biotopes of the island included marshy, salty meadows situated in the south-western part of the island, where several halophilous species, rare in Poland, could be encountered (Kornobis 1979). As for the few inwood peat bogs and marshy forest valleys which were the major type of water habitats in the western part of the island and had a considerable nature value, little was known about their fauna.

The objective of the present study was to specify the species diversity and species abundance of water beetles in a number of water bodies, taking into account selected environmental factors, including: hydroperiod, area of the investigated water bodies, their maximum depth, percentage of water surface shaded by plant canopy, and vegetation structure, i.e. the share of emergent and submerged macrophytes.

Furthermore, the study also aimed at expanding the knowledge about the water beetle fauna of Wolin Island.

Study area

The study was conducted in five dystrophic water bodies situated in the north-western part of Wolin Island, on the boundaries of the harbour part of the city of Świnoujście. The studied region was characterized by the belt-like structure of terrain, and particular biotopes were parallel to one another. Three pools (numbers 1, 2 and 5) were situated in a depression covered with an alder swamp and an alder riparian forest. They were similar in size (ca. several hundred square meters) and depth (ranging from 0.9 to 1.2 m), characterized by a comparatively large percentage of shading (60–75% of the surface), but differed with respect to the amplitude of water levels and the structure of vegetation. In reservoirs no. 1 and 2, despite their considerable astaticity, water was present until the end of the investigation period, while reservoir no. 5 showed a tendency to dry out periodically. Towards the end of May there was observed a dramatic drop in its water level, and water remained present only in few, small puddles. As a result of subsequent precipitation the water level in reservoir no. 5 increased. In the pool no. 1 vegetation was dominant and represented mainly by. *Lemna trisulca*, which grew intensely during the vegetation season, and the submerged shoots of *Sparganium* sp. The emergent vascular vegetation, represented by *Phragmites communis*, was far less common. As for the reservoir no. 2, it was covered with loosely growing reeds and the underwater and pleustonic vegetation, definitely less numerous than in the reservoir no. 1, represented by submerged leaves of *Sparganium*, *Lemna trisulca*, vernal water-starwort (*Callitriche palustris*), and very scarce *Sphagnum*. Typical helophytes, represented mainly by *Glyceria*, dominated in the reservoir no. 5, but in this particular reservoir there was also present well-developed submerged and pleustonic vegetation (*Sparganium* sp., *Lemna trisulca*, *Riccia* sp.)

The remaining two reservoirs were situated within a lowland peat bog separated from the alder swamp by a belt of forested hills Both these reservoirs were characterized by a low percentage of shading (25–35%), but they differed with reference to the area of water surface, maximum depth and permanence. Reservoir no. 3 was rather small (ca. 10 m^2), its maximum depth was up to 1 m and it was a permanent water body. Its emergent vegetation was represented by a clump of rushes and banks covered with grasses, sedges and a single willow shrub. Reservoir no. 4 was a periodical pool with the surface of ca. 650 square meters and was rather shallow: its depth did not exceed 0.5 m. The changes in its hydrological regime were similar as in the case of the reservoir no. 5, but showed greater intensity. Already in the middle of May there was observed a dramatic drop in the water level, and in June the pool dried out completely. Torrential rains in July partly refilled the reservoir and a low water level was present until the end of the investigation period. In this reservoir the submerged vegetation was dominant and represented mainly by grasses and *Hottonia sp*., which covered nearly 65% of the reservoir surface. Emergent plants included sedges, osiers and rather few clumps of rushes.

The investigated water bodies were situated at various distances with reference to one another. Reservoirs no. 1 and 2 were situated in a close proximity, as well as reservoirs no. 3 and 4, while reservoir no. 5 was situated the farthest from the others. However, the maximum distance between any of the two reservoirs did not exceed 550 m. Synthetic data referring to the environmental characteristics of particular reservoirs is shown in Table 1.

Table 1. Ecological characteristics of the investigated water bodies, featuring the analyzed environmental factors

Water body	Maximum area (m^2)	Maximum depth (m)	Permanence during 7 months of field investigation (months)	Share of emergent macrophytes (%)	Share of submerged macrophytes and plustonic plants (%)	Water surface shade by plant canopy (%)	Water body type
1	470	0.90	7	15	45	70	Permenent
2	540	1.20	7	50	15	60	Permanent
3	10	1.00	7	15	30	30	Permanent
4	650	0.50	5.5	20	65	25	Temporary
5	560	0.80	6	45	30	75	Semi-permenent

Materials and methods

The samples were collected monthly, since April until October 2007 with a standard hydrobiological sweep net. The size of samples was constant and amounted to 15 sweeping movements per habitat type in a particular water body.

The habitat types included the following: patch of emergent vegetation, patch of submerged vegetation, and ecotone. Additionally, for a period of one week every month, in habitats associated with particular vegetation types, there were set passive traps made of plastic bottles with capacity of 1.5 dm^3, equipped with a funnel entry, 2.2 cm in diameter. The collected samples were preserved in alcohol, segregated and labeled in the laboratory.

In order to investigate the correlation between species composition and chosen environmental factors there was employed the canonical correlation analysis (CCA) supported by the CANOCO software. The analyzed environmental variables included: area of water bodies and their maximum depth (measured according to the metric scale), and also: the percentage share of emergent and submerged vegetation with reference to the surface of particular water bodies and the percentage of water surface shadowed by plant canopy. The analysis also took into account such factors as the permanence of the investigated water bodies expressed by the number of months during the study period when water was covering at least 5% of their bottoms. The structure of faunistic similarity of particular localities was established with the help of Bray-Curtis formula, while the biodiversity of beetle assemblages was calculated on the basis of Shanonn-Wiener Index (H` base log 10) and with the help of BioDiversty Pro. In order to specify the structure of dominance there was applied the division into: eudominants (> 10%), dominants (5.1–10%), subdominants (2.0–5.0%) and recedents (> 2%) (Biesiadka, Kowalik 1980).

Results

The presence of 60 species of water beetles was recorded within the investigated area. They were representative of 8 families: Haliplidae (4 species), Noteridae (2) Dytiscidae (35 species), Hydraenidae (3), Helophoridae (3), Hydrochidae (2) Hydrophilidae (10), and Spercheidae (1 species) (Table 2). In total, in all reservoirs there were collected over 2.6 thousand of specimens. Tyrpophilous and tyrphobiontic forms constituted 30% of all species, being the most numerous in peat bog communities, while the remaining species were either characteristic of small water bodies or eurytopic. The most valuable elements of the Coleoptera fauna in the investigated area were the species endangered with extinction in Poland, such as: *Haliplus apicalis* Thoms., *H. furcatus* Seidl., *H. variegatus* Sturm, and the critically endangered species *Spercheus emarginatus*

(Schall.) (Głowaciński 2002). Furthermore, there was recorded the presence of species rarely encountered in Poland, namely *Helophorus nanus* (Sturm), *Hydroporus incognitus* Sharp, and *Colymbetes striatus* (L.)

Table 2. Taxonomic composition and species abundance in particular water bodies

Taxa	Code of taxon	Total number of specimens in the water bodies				
		No. 1	No. 2	No. 3	No. 4	No. 5
1	2	3	4	5	6	7
Haliplis apicalis Thoms.	*Hal.api*	0	0	0	3	0
Haliplus furcatus Seidl.	*Hal.furc*			2		
Haliplus heydeni Wehncke	*Hal.hey*	0	1			
Haliplus variegatus Sturm	*Hal.var*	0	6			
Noterus clavicornis (De Geer)	*Not.cla*	0	1			
Noterus crassicornis (O.F. Müll.)	*Not.cra*	0	54		13	
Hydroporus angustatus Sturm	*Hpor.an*	0		3	9	1
Hydroporus incognitus Sharp	*Hpor.in*	0		1	3	
Hydroporus neglectus Schaum	*Hpor.ne*				21	1
Hydroporus palustris (L.)	*Hpor.pa*				1	
Hydroporus planus (Fabr.)	*Hpor.pl*			2		
Hydroporus tristis (Payk.)	*Hpor.tr*		1	46	15	3
Suphrodytes dorsalis (Fabr.)	*Suph.dor*	7				1
Hygrotus decoratus (Gyll.)	*Hyg.dec*	58	32	79	498	83
Hyphydrus ovatus L.	*Hyph.ov*	2				
Copelatus haemorrhoidalis (Fabr.)	*Cop.hae*				2	4
Agabus affinis (Payk.)	*Aga.aff*	1			2	
Agabus bipustulatus L.	*Aga.bip*					2
Agabus uliginosus (L.)	*Aga.uli*				5	10
Agabus undulatus (Schrank)	*Aga.und*	1	8	4	24	21
Ilybius ater (De Geer)	*Il.ater*	4		2	1	1
Ilybius guttiger (Gyll.)	*Il.gutt*		1			
Ilybius neglectus (Erich.)	*Il.negl*		1		10	7
Ilybius quadriguttatus (Lac.)	*Il.quad*	12	3		2	9
Ilybius similis Thoms.	*Il.simi*			1	3	2
Ilybius subaeneus Erich.	*Il.sub*	1			2	6
Colymbetes fuscus (L.)	*Col.fus*	5	3		6	8
Colymbetes paykulli Erich.	*Col.pay*		1		1	4
Colymbetes striatus (L.)	*Col.str*		3		4	6
Rhantus frontalis (Marsh.)	*Rh.fron*	1				
Rhantus grapii (Gyll.)	*Rh.grap*	4	1			

1	2	3	4	5	6	7
Rhantus suturalis (Mac Leay)	*Rh.sutu*			2		
Acilius canaliculatus (Nic.)	*Aci.can*	2			1	2
Acilius sulcatus (L.)	*Aci.sul*		1		2	3
Graphoderus zonatus (Hoppe)	*Gra.zon*	2				1
Dytiscus circumcinctus Ahr.	*Dyt.cir*	1			1	1
Dytiscus dimidiatus Bergstr.	*Dyt.dim*	6			1	2
Dytiscus marginalis L.	*Dyt.mar*	2	6		6	2
Hydaticus continentalis J. Balf.-Br.	*Hyd.con*				1	
Hydaticus seminiger (De Geer)	*Hyd.sem*	4	6	1	13	17
Hydaticus transversalis (Pontopp.)	*Hyd.tran*	5			1	
Hydraena palustris Erichson	*Hdrn.pa*				1	
Ochthebius minimus (Fabr.)	*Och.min*	1	2	2	1	6
Limnebius parvulus (Herbst)	*Lim.par*	1		1		
Helophorus nanus (Sturm)	*Hlph.na*	1		56	5	1
Helophorus flavipes (Fabr.)	*Hlph.fl*			2		
Helophorus obscurus Mulsant	*Hlph.ob*			7		
Hydrochus brevis (Herbst)	*Hds.bre*			5	4	
Hydrochus carinatus Germar	*Hds.car*		3		4	2
Anacaena lutescens (Stephens)	*Ana.lut*	3	9	115	13	12
Berosus signaticollis (Charp.)	*Ber.sig*				1	
Cymbiodyta marginella (Fabr.)	*Cym.mar*		1	1		1
Helochares obscurus (O.F. Müll.)	*Hel.obs*				1	
Enochrus melanocephalus (Olivier)	*Eno.mel*			1	2	
Enochrus quadripunctatus (Herbst)	*Eno.qua*				4	
Hydrobius fuscipes (L.)	*Hdb.fus*		19	34	56	28
Hydrochara caraboides (L.)	*Hdch.ca*	25	73	10	547	280
Cercyon convexiuscuslus Steph.	*Cer.con*	2	9	1	3	9
Coelostoma orbiculare (Fabr.)	*Coel.or*		1			
Spercheus emarginatus (Schall.)	*Spr.ema*			1	1	
Dytiscus sp.	*Dyt.sp*	0	10	0	8	27
Dytiscidae non det	*Dytsid*	22	0	0	7	0
Total number of individuals		173	256	379	1309	563
Total number of species		23	24	23	42	31

The investigated water bodies differed from one another both with respect to species richness and abundance. The largest number of species (42) and specimens (1309) was collected in reservoir no. 4 (Table 2). However, the beetle assemblage in this particular reservoir was strongly dominated by two taxa: *Hydrochara* *caraboides* (L.), which constituted 41.8% of the total number of beetles in samples, and *Hygrotus decoratus*, whose share amounted to 31%. As for the other species, solely *Hydrobius fuscipes* (L.) reached the subdominant status having the share of 4.3%. The remaining species were classified as recedents. As a result of such dominance structure, the Shannon-Wiener Index (H`) of biodiversity calculated for the assemblage in question amounted to 0.705 and was the lowest among all of the investigated beetle assemblages. Reservoir no. 5 was characterized by a less rich species composition (31 species) and a clearly lower abundance of Coleoptera fauna (563 specimens). However, the beetle assemblage in this reservoir had a similar dominance structure as its counterpart in reservoir no. 4. Namely, in reservoir no. 5 the eudominant species were also *H. caraboides* and *H. decoratus*, which constituted, respectively, 49.7% and 14.7% of the total number of beetles collected from this reservoir. The subdominants, apart from *H. fuscipes* (5% share in the assemblage), was also represented by *Agabus undulatus* (Schrank) (3.7%), *Hydraticus seminiger* (De Geer) and *Anacaena lutescens* (Stephens), which constituted, respectively, 3% and 2.1% of the total number of individuals collected in this locality. The remaining species had the status of recedents. The value of biodiversity index for the beetles in reservoir no. 5 was 0.841. Reservoirs 1–3 were characterized by a similar level of species richness (23–24 taxa), while the abundance of collected beetles ranged from 173 (reservoir no. 1) to 379 (reservoir no. 3) (Table 2). Beetle assemblages inhabiting the reservoirs in question, in comparison to reservoirs no. 4 and 5, were characterized by a more balanced dominance structure. In the locality no. 1 there were observed two eudominant species, *H. caraboides* and *H. decoratus* (14.5% and 33.5% share in the assemblage, respectively), one dominant *Ilybius quadriguttatus* (Lac.) (6.9%), and six subdominants, among which *Suphrodytes dorsalis* (Fabr.) had the largest share in the assemblage (4%). Also in reservoir no. 2 the eudominants included *H. caraboides* and *H. decoratus* (28.5% and 12.5%, respectively), and *Noterus crassicornis* (O.F. Müll.), which had the 21.1% share in the assemblage. The dominant status was reached by *Hydrobius fuscipes* (L.), constituting 7.9% of specimens collected in the reservoir in question. Seven beetle species (including *Haliplus variegatus*) were subdominants and their share in the assemblage ranged from 2.3 to 3.5%. In the reservoir no. 3 eudominants included four species, namely: *Hydroporus tristis* (Payk.), *Helophorus nanus*, *Hygrotus decoratus*, and *Anacaena lutescens*. Their percentage share in the collected material amounted to: 12.1%, 14.8%, 20.8%

and 30.3%, respectively. In this assemblage the dominant species was *Hydrobius fuscipes*, constituting 7.4% of beetles in samples, while the subdominant species was *Hydrochara caraboides* with the share of 2.6%. A specific feature of the Coleoptera fauna of the reservoir in question was the absence of representatives of large predaceous diving beetles belonging to the genera *Dytiscus*, *Colymbetes* and *Acilius*, which were encountered in the other reservoirs (Table 2). Shannon-Wiener Index amounted to 0.991 in reservoir no. 1, 0.981 in reservoir no. 2 and 0.889 in reservoir no. 3. In reservoirs no. 4 and 5 there were observed characteristic fluctuations in the abundance of collected beetles, correlated with the changes in hydrological regime. These fluctuations consisted in the increasing number of collected beetles as the water level in reservoirs was decreasing at the beginning of May. Further loss of water was connected with the disappearance of Coleoptera fauna, and after the refilling of reservoirs the number of collected beetles was still low. On the other hand, in reservoir no. 2, which was the least vulnerable to changes of water level, the fluctuations in the number of collected beetles were not that significant.

Reservoirs no. 4 and 5 were the most similar ones with respect to the species composition and abundance, with Bray-Curtis similarity coefficient amounting to 53.2%, followed by reservoir no. 2 with 44.8%. Together with reservoir no. 1 they formed a group characterized by the similarity coefficient of 38.7% (Fig. 1). On the other hand, reservoir no. 1 represented faunistic separateness and constituted an individual branch of the dendrogram, connected with the other reservoirs by the assemblage similarity coefficient of 31.4%. It is noteworthy that the pairs of neighboring reservoirs no. 1 and 2, as well as no. 3 and 4, were characterized by a significant faunistic dissimilarity. Faunistic similarities between particular reservoirs might be associated with their ecological characteristics. Reservoirs no. 4 and 5 were characterized by the least steady hydrological conditions, as they were actually periodical reservoirs, while reservoir no. 3 showed the most significant environmental separateness, especially with reference to its surface and the structure of vegetation.

The CCA analysis investigating correlations between species composition and environmental factors showed that the significance of the reservoir area in shaping beetle assemblages was statistically valid ($p = 0.040$) and explained 34.8% cases of species variability in these assemblages. As for some other studied parameters, certain significance in shaping the assemblages was observed in correlation with such factors as reservoir permanency and the presence of emergent plants, but similarly to the three other factors (i.e. maximum depth, presence of submerged and pleustonic plants, shading of water surface) they did not reach the threshold of statistical validity. On the other hand, there could be distinguished a group of twenty species, for which the crucial factor in the process of habitat selection was its size, as they preferred the larger reservoirs. There could also be distinguished an assemblage of nine taxa inhabiting small but relatively deep reservoirs, represented in the study by reservoir no. 3 (Fig. 2). Several species showed a loose association with permanent shaded waters. A group of seven species showed a tendency to inhabit reservoirs with a large share of emergent vegetation. This group included i.a. *Haliplus variegatus*, collected solely in reservoir no. 2, to a large extent covered by helophytes. However, the distribution of this species was influenced by other environmental parameters, such as the lower level of eutrophication or the specific floristic composition of the reservoir. There was also observed a group of ten taxa, visible on the chart as a clearly separate group, for which no definite interrelation with any of the studied parameters could be definitely proved.

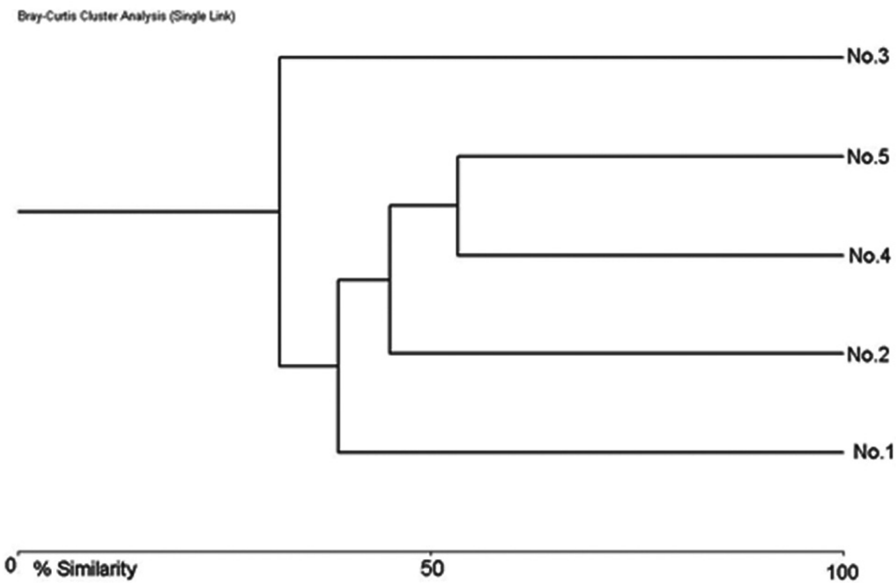

Fig. 1. Dendrite of quantitative faunistic similarities among the investigated water bodies (No. 1–No. 5)

Discussion

Although the investigated area was rather small and the investigated water bodies rather few, the collected material was exceptionally rich. In comparison, within the spacious lowland peatbog “Krępskie Bagno”, also situated in the West Pomerania, there had been recorded just 75 beetle species (Zawal et al. 2004), and in the area of a large mud and peat bog complex of Korenburgerveen (The Netherlands) there had been recorded 67 taxa (Verberk et al. 2002). The species composition of the collected material was characterized by a large share of tyrpophilous and tyrphobiontic forms and the dominance of species common to small water bodies as well as eurytopic species, while the species characteristic of other ecological assemblages were very few. This confirmed the dystrophic character of investigated water bodies and a significant degree of their isolation. The significance of the faunistic aspect of the conducted research was rised by the fact that it supplemented the studies on beetle occurrence in Wolin which had been conducted at least 30 years ago and encompassed other areas of the island (Podgórniak, 1960, Kornobis 1979). The present study resulted in adding 25 new taxa to the list of almost 100 beetle species encountered in this region of Poland. Among the new additions there were the above mentioned valuable species belonging to the genera *Haliplus* and *S. emarginatus*. The fact that *Hygrotus decoratus* (Gyll.) was found in large numbers in one of the investigated localities confirmed the observation of Podgórniak (1960), according to whom abundant local populations of this beetle could be encountered in Wolin Island.

The conducted research allowed to observe significant differences among the Coleoptera fauna of particular reservoirs, with respect to species richness, dominance structure and also general abundance. It ought to be stressed that the differences were observed within the system of habitat types situated in a close proximity and closely related ecologically, and these differences referred to a group of invertebrates possessing a large migration potential and representing a wide spectrum of ecological valence.

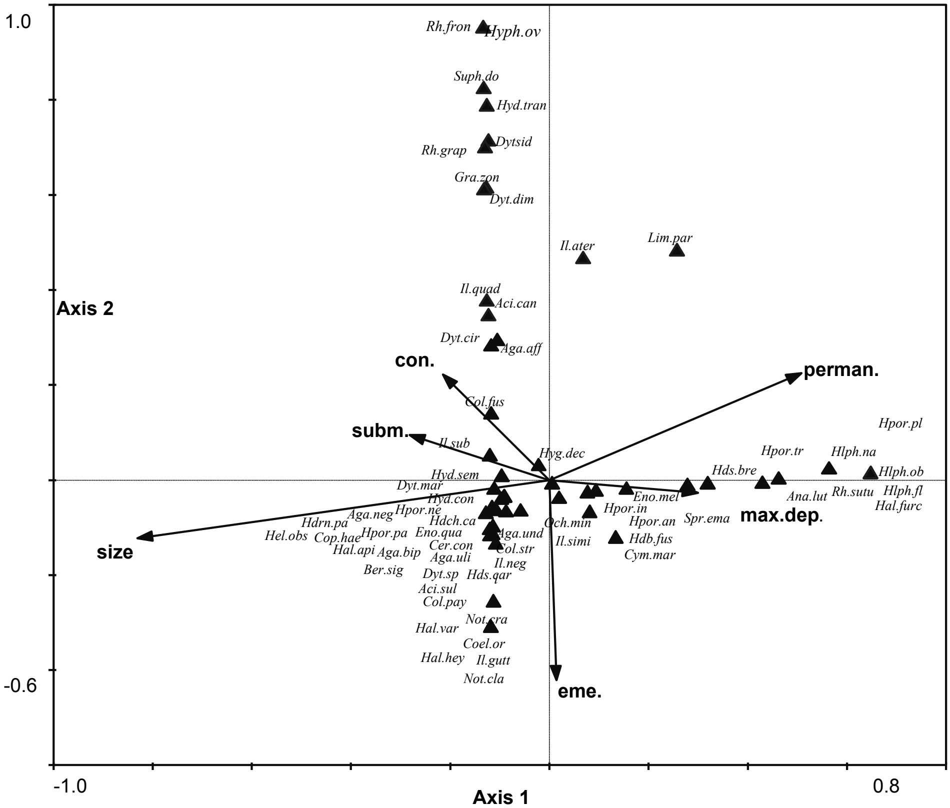

Fig. 2. CCA plot showing species and environmental variables: size of the water body (size), permanence (perman.), maximum depth (max. dep.), share of emergent vegetation on the water surface (eme.), share of submerged and pleustonic vegetation on the water surface (subm.), water surface shaded by plant canopy (can.). Data describing the species is provided in Table 2. Among the six analyzed environmental variables accounting for species diversity only the size of water bodies reached the level of statistical validity

Habitat conditionings were the cause of assemblage diversification, however, these conditionings influenced the general quantitative and qualitative relations in assemblages rather than constituted a selective factor whose influence was directed at particular species. Surface size of the reservoirs was an exception, since it determined the occurrence of over one third of species in the assemblages. The significance of the reservoir size in the shaping of beetle assemblages had already been noted by Rundle et al. (2002), who observed a positive correlation between the species richness of beetles and the permanence and maximum size of reservoirs. Furthermore, the correlation with respect to surface size of reservoirs was discovered to be more important than the correlation with respect to their permanence. The analyses conducted by Sanderson et al. (2005), investigating the occurrence of selected components of the macrofauna in the mosaic system of small water bodies in association with a number of environmental parameters confirmed the significant influence of reservoir size on the whole macrofauna. However, according to the above mentioned authors, the permanency of water reservoirs exercised a stronger influence over both the whole assemblage of invertebrates and the group of studied beetles (4 species). Moreover, Nilsson and Svensson (1995) also discovered a strong correlation between the beetle species richness and density and the combination of such parameters as depth, area and temperature of small subpolar water bodies.

The permanency of water biotopes is one of the key environmental parameters determining the shaping of beetle assemblages (Foster et al. 1992, Rundle et al. 2002, Sandersn et al. 2005). To a certain extent it acts as a selective factor directed at particular species (Fairchild et al. 2003), but at the same time it influences the assemblage in general by determining the general species richness, which becomes higher with the lengthening of the reservoir's hydroperiod (Collinson et al. 1995, Wiliams 1996). Paradoxically, within the complex of the investigated small water bodies in the neighborhood of Świnoujście, the highest species richness and beetle abundance were observed in the two periodical reservoirs (no. 4 and 5), which were, additionally, characterized by a significant similarity with respect to the investigated fauna and the dynamics of changes in the assemblages. This phenomenon may probably be explained by such factors as a) Coleoptera fauna composition, teeming with species characteristic of small water bodies as well as eurytopic and trypohilous species, which are characteristically encountered in astatic waters in spring and well-adjusted to such environment, b) good habitat conditions (especially in the reservoir no. 4) and c) prolonged hydroperiod of the reservoirs. Water beetles belonging to the above mentioned ecological groups may create comparatively rich and diversified assemblages in ephemeral waters (Biesiadka & Pakulnicka 2004), where they constitute one of the most important faunistic elements (Collinson et al. 1995, Zawal et al. 2004). Even though it had already been discovered that shallow, well exposed water bodies covered with submerged vegetation were the type of biotope preferred by the Coleoptera fauna (Foster et al. 1992), it was difficult to explain its abundance in reservoir no. 5. After eliminating the role of surface size and the degree of shading, which were similar to reservoirs no. 1 and 2, not inhabited by such large numbers of beetles, and the role of distance (the reservoir in question was the most isolated of all), the most significant factor became the diversified vegetation structure. The importance of vegetation structure in the shaping of species composition and density of beetles had been highlighted in the studies by Sanderson et al. (2005) and Cooper et al. (2005).

The percentage share of water surface shaded by plant canopy did not have a significant influence on the species composition of beetle assemblages. However, the factor in question might play a part in the shaping of the general species richness and abundance of beetles in some of the investigated water bodies. In the pools where the water surface was to a large extent shaded by the surrounding plant canopy (reservoirs no. 1 and 2) the number of species was almost twice lower, and the number of collected species was even eight times lower, than in reservoir no. 4 which was an unshaded one. In the case of reservoir no. 3 the significance of the unshaded water surface was probably diminished by its small size. As a result, its species richness reached a similar level as in reservoirs no. 1 and 2, while the abundance of beetles was higher in reservoir no. 3. The assumed influence of the shaded water surface on the Coleoptera fauna was not discovered in reservoir no. 5. Binckley & Resetarits (2007) observed enormous decrease of species diversity and abundance of beetles inhabiting shaded environments and the increase of fertility in some species inhabiting the water bodies with unshaded surfaces. Also Nilsson & Svensson (1995) observed a quicker pace of colonization in experimental pools dug out in deforested areas as compared to the counterparts of such pools situated in forests. Moreover, they observed the change of species composition, i.e. the withdrawal of stenotypic species from the unshaded pools and their replacement by eurytopic species. The significance of the unshaded water surface as a factor determining the richness and abundance of beetle species in the investigated system of water bodies has to be considered in the context of the random character of fauna dispersion. The fact that the water surface is shaded diminishes the probability that all migrating species will settle in the reservoir, and thus it constitutes a selective factor. As was suggested by the research conducted by Binkley and Resetarits (2005), the process of habitat selection goes through the stage of behavioral evaluation of the environmental parameters and results either in the tendency to migrate further or in the tendency to settle down, entailing the adjustment of species structure and species abundance of beetles to the encountered conditions.

Both the conducted research and the subject literature indicate that there exists a certain group of environmental factors responsible for the shaping of qualitative and quantitative structure of beetle assemblages inhabiting small astatic water bodies. The significance of these parameters, which are an element of a complex, locally conditioned network of ecological interrelations, may vary from one assemblage to another. The large dispersion potential, mobility and a low degree of ecological specialization of water beetles make it even more difficult to establish a general pattern of variability of this type of fauna in small water bodies.

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