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ROTIFER AND CLADOCERAN DIVERSITY IN SMALL WATER BODIES UNDERGOING DIFFFERENT ANTHROPOGENIC IMPACT IN THE WIELKOPOLSKA REGION

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Abstract: The paper presents the results of an investigation of physical-chemical features of water and their impact on rotifer and crustacean diversity structure, relating to the taxonomic richness and species diversity index, in eight small water bodies differing in the trophic status. The analysis included stands located in the unvegetated zone (the open water area) as well as among different ecological types of aquatic vegetation (helophytes and elodeids) because in small water bodies the pond's bottom is usually overgrown by aquatic vegetation.

Only two ponds were of mesotrophic character, while six were eutrophic and hypertrophic. High trophic conditions on average were a result of external loading in nutrients, coming from the agricultural catchment area. An analysis of % participation of zooplankton eutrophic species indicated a positive relationship with the trophy indices and chlorophyll *a* concentration, while a negative relationship with water transparency was noted only for rotifers in small water bodies located within agricultural areas of different levels of anthropogenic transformation in the Wielkopolska region. These animals also revealed a positive correlation between the species diversity and pH, oxygen concentration and water transparency as well as a negative relationship between the number of species with conductivity and total nitrogen. These suggest that the increase in the water quality will favour the more diverse and stable taxonomic composition in the case of rotifers. Cladoceran diversity structure was only positively related to water reaction. This might be a result of the quite poor taxonomic structure of this group of zooplankton, regardless of the trophic conditions related to human impact and thus the effect of water degradation in the ponds within the pastoral landscape. Moreover, taking into consideration vegetated stands within the pond's area did not support high values of Shannon-Wiever diversity index in the case of this group of zooplankton. Contrary to cladocerans, rotifers species diversity was much higher and differed significantly between particular stations, with the highest values among the most heterogenic habitats – elodeids and helophytes.

Keywords: small water bodies, mid-field catchement area, trophic conditions, water chemistry, zooplankton

INTRODUCTION

Small water bodies, which have been neglected by researchers for years, belong to ecosystems which create favourable conditions for a variety of organisms (Oertli et al. 2002), and contribute to the maintenence and enrichment of biodiversity (Hawksworth 1996).

The functioning of a pond depends on various environmental factors among which the concentration of nutrients, especially of nitrogen and phosphorus, physical factors such as pH, dissolved oxygen, conductivity or water transparency are among the most important when considering its inhabiting organisms (Joniak et al. 2007). The physical and chemical features will also have an impact on the development of specific macrophyte coverage (Bosiacka & Radziszewicz 2002), which in turn will contribute to the creation of specific communities of animal plankton.

The trophic condition of a water body is usually equated with the amount of biogenic substances dissolved in water and deposited in the sediments, passing over biogens deposited in the zone of littoral, which quite often covers the whole bottom of a pond. Therefore trophy usually relates to lakes (Kajak 2001), though it also concerns small water bodies. The water quality of a particular reservoir relates to the character of the neighbouring area. The amount of contamination which is deposited in the pond will usually be connected with the type of catchment area surrounding the small water body (Joniak et al. 2007). The effect of the type of landscape is well documented in the case of lakes or small rivers (Ryding & Rast 1989; George & Winfield 2000; Dodson et al. 2007; Nessimian et al. 2008), however, the data concerning small water bodies are still insufficient. Hence, the functioning of small water bodies will also reflect the type of the surrounding area and the level of anthropogenic transformation in the catchment area. This is why the main aim of this study was to estimate the range of abiotic features of the aquatic environment and their impact on the species composition of rotifer and cladoceran communities in mid-field small water bodies undergoing anthropogenic influence of different levels of intensity.

Ponds, which are usually shallow and small ecosystems, may create an abundance of different habitats within a restricted area, especially thanks to different species of aquatic vegetation occurring in single or mixed-species plant stands. Macrophytes may be of a different shape, length and width of stems and also of a different surface structure. Particular beds of aquatic plants may differ in e.g. density, spatial orientation of stems, cover percentage or biomass. Two different ecological types of water vegetation, represented by rush and submerged macrophytes, differ significantly in morphological and spatial build and create different habitat conditions for inhabiting organisms. Hence, the additional purpose of this study was to examine the diversity of rotifer and cladocerans inhabiting various habitats of the pastoral ponds. Water vegetation of such ecosystems tends to create a mosaic of habitats, which is a characteristic feature of ponds (Ozimek & Rybak 1994).

MATERIAL AND METHODS

All the examined water bodies were situated in the agricultural landscape of the Wielkopolska Lowland, western Poland. They were all shallow and macrophyte-dominated ponds with a surface area between 0.05 and 1.6 ha and maximum depth between 0.3 and 2.3 m.

The research was carried out on eight ponds in the summer season of 2010. The samples were collected from the various phytocoenosis of aquatic vegetation, including elodeids – in communities dominated by *Ceratophyllum submersum* L. (pond 1), *Ceratophyllum demersum* L. (pond 4 and 7), *Potamogeton crispus* L. (pond 3) and *Potamogeton pectinatus* L. (pond 5), the zone of helophytes – in the communities dominated by *Typha angustifolia* L. (pond 7), *Typha latifolia* L. (pond 4) and *Phragmites australis* (Cav.) Trin. ex Steud. (pond 2 and 6) and the zone of open water surrounding the vegetation beds (pond 1–8).

Zooplankton material was taken in triplicate (n = 51) at each site using a plexiglass core sampler (∅ 50 mm), which is the method advised for studies within the littoral zone (Schriver et al. 1995). The 5 L samples were concentrated using a 45-µm plankton net and fixed immediately with 4% formalin.

Temperature, dissolved oxygen (DO), pH, electric conductivity (EC) and Secchi depth were measured directly at the sampling sites. Water samples were collected in order to analyse the chemical content (total phosphorus – TP, total reactive phosphates – TRP, nitrate – N_{NO3}, nitrite – N_{NO2} and ammonium nitrogen – N_{NH4}) using methods advised by Hermanowicz et al. (1999). Chlorophyll *a* was determined fluorometrically and corrected for degradation products according to Lorenzen (1966) and its concentrations was given as active photosynthetic pigments. Water trophy was assessed according to the Carlson (1977) classification. The level of the trophic conditions TSI_{Tot} was related to the ranges proposed by Kraska et al. (1999).

The Kruskal-Wallis test was used in order to determine the effect of site and pond on rotifer and cladoceran densities (N = 51). The correlation between physicochemical parameters and zooplankton diversity was defined using Pearson's linear correlation coefficient.

To define the species diversity of zooplankton inhabiting different water bodies and diferent types of water vegetation the Shannon-Weaver index was applied (Margalef 1957).

RESULTS

The examined water bodies were characterised by light alkaline to alkaline reactivity of water (from 7.54 to 9.16). Conductivity was high in all the ponds and reached values of between 610.0 and 2075.3 µS × cm^{-1}. There were great differences in the water oxygenation with the mean values at a level of 95% (tab. 1).

Mean values of the total phosphorus were high and accounted for 0.68 mg × l^{-1}, however differences between particular ponds were considerably high, from the lowest in ponds 1, 2 and 3 (from 0.035 to 0.063 mg × l^{-1}) defining good conditions of water for non-stratified water bodies to very high in ponds 6 and 7 (from 1.255 to 2,639 mg × l^{-1}). Similar differentiation concerned concentrations of nitrogen forms (Tab. 1).

Physical-chemical analysis also revealed differences between particular habitats (Tab. 1).

Table 1. The physical-chemical characteristics of water of the examined water bodies

Pond No.	station	pH	cond µS/cm	O_2 %	widz (m)	Chl a µg/l	TP mg/l	NH_4 mg/l	NO_3 mg/l	NO_2 mg/l	TSI tot	trophy
1	Water	7.54	1086.3	65.3	1.9	14.14	0.047	0.91	0.32	0.005	166.91	á-mezotrophy
1	Elod	8.91	1037.3	122.0	1.9	12.56	0.063	0.81	0.28	0.006	170.08	á-mezotrophy
2	Water	7.87	1342.7	172.0	1.05	19.14	0.035	0.41	0.09	0.003	154.25	á-mezotrophy
2	Heloph	7.99	1364.7	145.0	1.05	15.00	0.037	0.57	0.07	0.001	172.50	á-mezotrophy
3	Water	7.75	612.0	62.7	0.4	16.24	0.035	0.43	0.05	0.003	186.45	eutrophy
3	Elod	7.86	610.0	69.0	0.4	13.32	0.043	0.49	0.05	0.003	187.43	eutrophy
4	Water	9.14	1296.0	89.1	1.5	9.07	0.169	0.49	2.35	0.010	184.48	eutrophy
4	Heloph	9.16	1300.0	101.8	1.5	32.70	0.265	0.33	1.55	0.012	203.58	eutrophy
4	Elod	9.18	1300.0	119.2	1.5	35.70	0.238	0.69	1.68	0.013	202.91	eutrophy
5	Water	8.36	1624.7	76.0	0.3	31.97	0.620	1.15	0.88	0.013	238.83	eutrophy
5	Elod	8.62	1594.0	101.7	0.3	69.08	0.566	0.79	1.02	0.013	245.42	eutrophy
6	Water	8.36	2072.7	9.0	0.2	14.73	1.255	4.92	0.30	0.013	247.26	eutrophy
6	Heloph	8.36	2075.3	11.0	0.2	29.50	1.307	5.07	0.31	0.012	254.65	eutrophy
7	Water	8.20	906.0	113.0	0.4	56.01	2.639	1.20	0.11	0.003	261.08	eutrophy
7	Heloph	8.10	900.7	89.7	0.4	46.53	1.704	1.41	0.09	0.002	252.96	eutrophy
7	Elod	8.16	902.0	105.7	0.4	48.58	1.983	1.63	0.10	0.003	248.91	eutrophy
8	Water	8.86	766.0	166.0	0.1	405.60	0.530	1.97	0.28	0.087	277.33	hypertrophy

Trophic conditions in the eight investigated water bodies differed significantly (KW – $H_{7,51}$ = 46.633, $p < 0.001$) and revealed a high range – TSI_{Tot} between 167–278, depending on a particular pond or the examined station (Fig. 1). Two ponds were classified as a-mesotrophic water bodies – TSI_{Tot} 167–174 (Pond 1 and 2), five ponds as eutrophic – TSI_{Tot} 167–174 (Pond 3–7) and one as

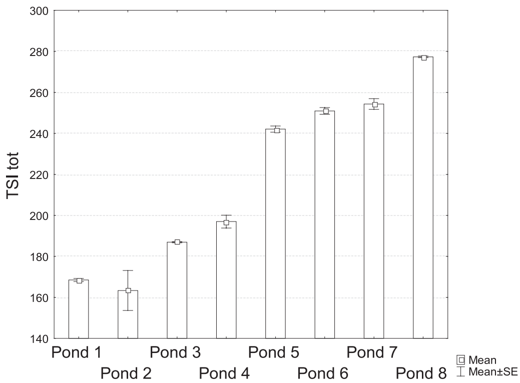

Fig. 1. The Carlson classification of the trophic conditions (TSI) between particular ponds

hypetrophic – TSI_{Tot} 276 (Pond 8). In most cases phosphorus was a decisive factor, responsible for the value of the index.

High trophic conditions in the waters of the studied ponds were also confirmed when analysing the dominating species of zooplankton community structure as well as the percentage participation of eutrophic species. In the group of ponds of low trophic conditions only one species – *Chydorus sphaericus* (O.F. Müller) dominated once among elodeids, while in the water bodies of eutrophic and hypertrophic character seven such species – *Anuraeopsis fissa* (Gosse), *Brachionus angularis* Gosse, *Filinia longiseta* (Ehrenberg), *Keratella cochlearis* f. *tecta* (Lauterborn) from among rotifers and *Bosmina longirostris* (O.F. Müller) and *Ch. sphaericus* from among cladocerans – occurred (Tab. 2). Two species: *B. angularis* and *Ch. sphaericus* dominated in two of the ponds, while the remaining eutrophic species dominated only in one pond. The mean % participation of eutrophy indicator species, irrespective of the station, differed between two groups of ponds. In the mesotrophic ponds it accounted for 25% of the total zooplankton densities, while in the case of ponds combining eutrophic and hypertrophic waters these species accounted for 35%.

There were 123 zooplankton species identified in total (99 of Rotifera, 24 of Cladocera). The range of rotifer species was quite high between particular ponds (between 9 and 38 species), while in the case of cladocerans the range was much lower (betwwen 0 and 9 species) (Fig. 2).

It was found that *Anuraeopsis fissa*, *Keratella cochlearis* (Gosse), *Lecane closterocerca* (Schmarda), *Lepadella patella* (O.F. Müller) and *Polyarthra remata* (Skorikov) from among rotifers occurred with the highest frequency (> 70%) in the examined material, while only one species – *Ch. sphaericus* from among cladocerans occurred with over 70% frequency.

Table 2. Dominating species of zooplankton in the examined water bodies

Pond	Pond 1	Pond 1	Pond 2	Pond 2	Pond 3	Pond 3	Pond 4	Pond 4	Pond 4	Pond 5	Pond 5	Pond 6	Pond 6	Pond 7	Pond 7	Pond 7	Pond 8
Station	Water	Elod	Water	Heloph	Water	Elod	Water	Heloph	Elod	Water	Elod	Water	Heloph	Water	Heloph	Elod	Water
Rotifera																	
Anuraeopsis fissa							x	x									
Bdelloidae										x		x	x				
Brachionus angularis					x	x								x	x	x	x
Brachionus quadridentatus										x	x						
Colurella uncinata		x							x								
Euchlanis dilatata											x						
Filinia longiseta															x	x	
Hexarthra mirra			x												x		
Keratella cochlearis	x		x	x													
Keratella cochlearis f. *tecta*					x	x											
Keratella paludosa													x				
Lecane bulla				x													
Lecane closterocerca								x									
Lepadella quadricarinata		x															
Polyarthra remata	x		x	x	x	x	x	x	x					x	x	x	
Polyarthra vulgaris	x											x	x				
Crustacea																	
Bosmina coregoni	x		x											x	x		
Bosmina longirostris														x	x		
Ceriodaphnia laticaudata												x	x				
Ceriodaphnia pulchella				x													
Ceriodaphnia quadrangula				x													
Chydorus sphaericus		x					x	x	x							x	x
Scapholeberis kingii										x	x						
Scapholeberis mucronata				x													

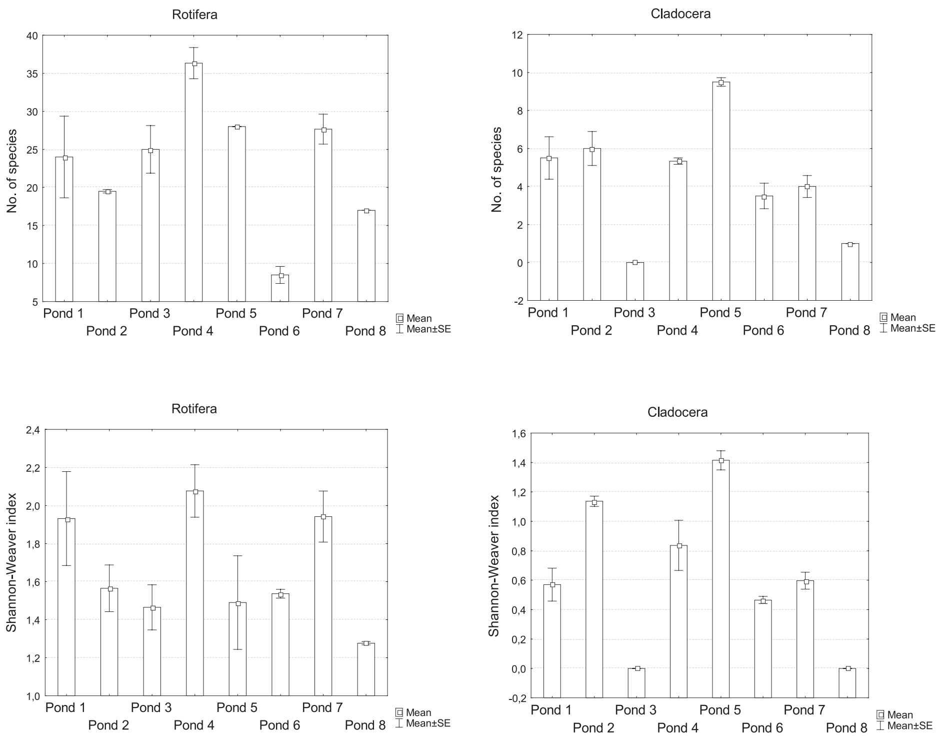

Fig. 2. The number of zooplankton species and values of Shannon–Weaver index between particular ponds

The Shannon–Weaver index of zooplankton diversity varied significantly between the types of ponds, with higher mean values among rotifers – mean values between 1.3 and 2.1 (KW – $H7_{,51} = 16.664$, $p < 0.05$) and lower among cladocerans – between 0 and 1.42 (KW – $H_{7,51} = 36.309$, $p < 0.001$) (Fig. 2). Moreover, species composition of both groups of zooplankton differed between particular stations, with the higher values found among vegeatated zones. In the case of the Shannon–Weaver index significant changes were only recorded among rotifers (KW – $H_{7,51} = 18.772$, $p < 0.001$), which reached the highest diversity among elodeids and helophytes. The index did not differ significantly ($p > 0.05$) among cladocerans, which reached the highest values in the zone of open water (Fig. 3).

There were 12 correlations between zooplankton species richness, Shannon–Weaver index values or % participation of eutrophic species and environmental parameters obtained (Tab. 3). Most of the relationships concerned the number of zooplankton species and participation of eutrophic species. Participation of zooplankton eutrophic species correlated positively with chlorophyll

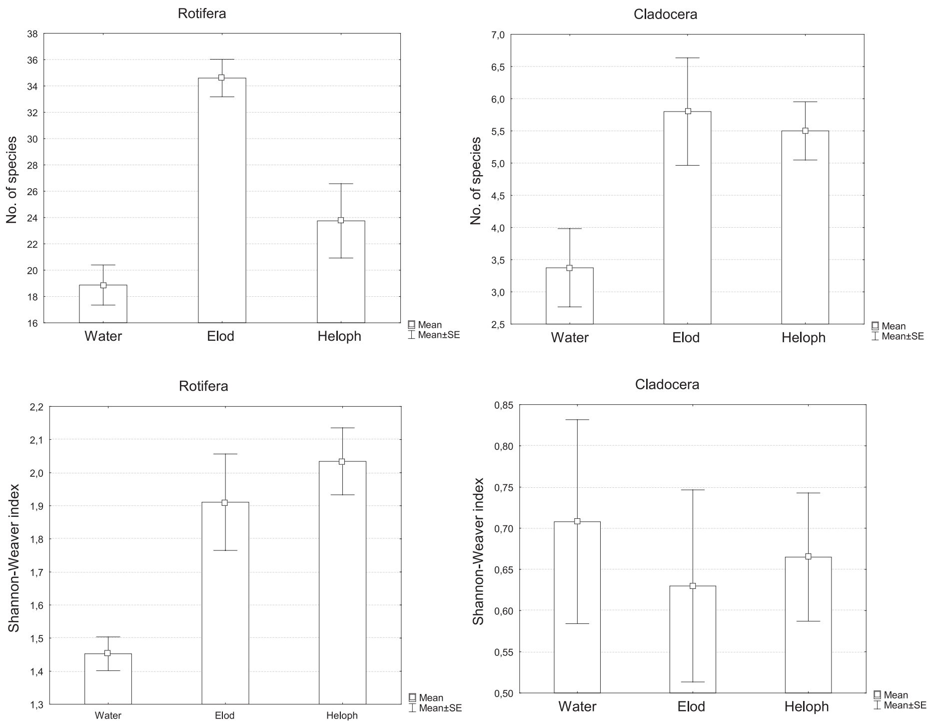

Fig. 3. The number of zooplankton species and values of Shannon–Weaver index between particular zones (Water – open water zone; elod – elodeids; heloph – helophytes) in the examined ponds

a concentration, total phosphorus, pH and TSI, while negatively with water

Table 3. The correlation ratios between the number of species (Nsp), Shannon–Weaver index (Sh–W) or % participation of eutrophic species (%eutr) of rotifers and cladocerans and physical-chemical variables (pH, conductivity – cond, oxygen concentration – O_2, water transparency – transp, total phosphorus – TP, total nitrogen – TN, chlorophyll *a* concentration – chl and TSI index) in the examined small water bodies

Group	Parameter	*r*	*p*	Parameter	*r*	*p*
Rotifera	%eutr vs. chl	0.518	< 0.001	Nsp vs. pH	0.519	< 0.001
	%eutr vs. transp	–0.437	< 0.001	Nsp vs. cond	–0.329	< 0.005
	%eutr vs. TSI	0.361	< 0.005	Nsp vs. O_2	0.365	< 0.005
	%eutr vs. TP	0.310	< 0.005	Nsp vs. transp	0.363	< 0.005
	Sh–W vs. pH	0.366	< 0.005	Nsp vs. TN	–0.366	< 0.005
Cladocera	%eutr vs. pH	0.409	< 0.005	Nsp vs. pH	0.344	< 0.001

transparency. Species richness revealed a positive correlation with pH, oxygen concentration and water transparency and negative with water conductivity and total nitrogen.

DISCUSSION

The results of many authors, dealing with both micro- and macroorganisms, prove that even within one single water body the life conditions may be modified by changes in the trophic conditions or changes in the intensity of environmental conditions. This will have a direct effect on the differentiation of communities of many organisms inhabiting these reservoirs (Szmeja 1987, 1994; Dodson et al. 2007), particularly if these water bodies are situated in the catchment area of different types of anthropogenic transformation.

Trophic conditions in the examined water bodies exhibited a high range – from a-mesotrophy, recorded in two ponds, to hypetrophy found in one pond. The concentrations of phosphorus had a decisive effect in most cases. Such a high variation in the trophic conditions can be a typical characteristics of small water bodies where the increase in the speed of eutrophy processes is not a rule, however, it can often be accelerated by the external loading of biogenic substances from the surrounding catchment area and also by the covering of the pond bottom by organic sediments (Hongve 1999). Moreover, alkaline pH along with high conductivity also indicates a contamination of waters by mineral compounds. It was not only the chemical features of the waters of the studied ponds that indicated high trophic conditions. The dominating structure of zooplankton species also confirmed this fact. It was noticed that the amount of dominating species of eutrophic character (Karabin 1985; Saksena 1987; Radwan et al. 2004) increased with the increase in the trophy of waters. In the two mesotrophic ponds only one cladoceran species – *Chydorus sphaericus* dominated, while in the eutrophic and hypertrophic ponds seven species – indicators of high trophy were recorded. Moreover, ponds of high trophic conditions (eutrophic and hypertrophic) were characterised by much higher participation of eutrophic species when compared with mesotrophic water bodies.

The changes in the trophic status of ponds may be quite sudden due to their small surface area, shallowness and small water volume in general. The morphometric parameters of small water bodies may in this case increase their susceptibility to degradation. This is especially important in the case of agricultural ponds, such as those undergoing examination. A differentiated inflow of nutrients into a certain water body may be caused by the type of land use and an accelaration of the human impact in the neighbourhood of a pond (Ryding & Rast 1989; George & Winfield 2000), and in consequence this will have an impact on the biocoenotic structure.

Trophic conditions of the examined water bodies had a great influence on the species diversity of zooplankton organisms and the participation of eutrophic species. An analysis of the relationship between zooplankton indices and physical-chemical factors indicated that the improvement in the water quality, stated by better water transparency and higher concentration of oxygen, will favour the more diverse and stable taxonomic composition in the case of rotifers. At the same time a negative relationship between the number of species with conductivity and total nitrogen proves these findings. Moreover, rotifer eutrophic species revealed a positive relationship with the trophy indices and chlorophyll *a* concentration, while a negative relationship with water transparency, which confirms the fact that the water quality of small water bodies located within agricultural areas of different levels of anthropogenic transformation in the Wielkopolska region have a significant effect on the structure of rotifer communities. In the case of cladocerans diversity structure correlated only with water reactivity. This might have been a result of poor taxonomic composition of these animals in the studied ponds, regardless of the trophic conditions.

Ponds, small ecological systems, often contribute to the enrichment of the local biodiversity, which is particularly important in the agricultural landscape. They may create favourable life conditions for many organisms, both producers and consumers (Hawksworth 1995). As a result of the examination carried out on eight ponds a presence of 123 zooplankton species in total was found, however, a great differentiation between particular ponds was noticed, especially in relation to rotifers. There were only six species (less than 5% of the taxonomic structure), whose frequency was higher than 70% (*A. fissa*, *K. cochlearis*, *L. closterocerca*, *L. patella*, *P. remata Ch. sphaericus*), which indicates a great variation of environmental factors between these small water bodies. Apart from *L. closterocerca* and *L. patella* the remaining species belong to forms associated with open water (Flössner 1972; Pejler 1995), so the optimum of their occurrence is found in the pelagic zone. Limnetic species may successfully live in the open water area during the daylight hours as some of them have evolved special morphological features which protect them from predator attack, such as long, bristle-like spines, which makes the capture of prey more difficult (e.g., *K. cochlearis*) or quick escape reactions (e.g., *P. remata*) (Lampert & Sommer 1993; Pejler 1995). Morphological defenses are usually related to cyclomorphological changes of the body shape or size (Spaak & Boersma 1997; Kappes & Sinsch 2002).

Aquatic vegetation is known to play a very important role in the structuring of communities of freshwater organisms thereby having an impact on the interactions between predators and prey and also acting as a source of food (Jeppesen et al. 1998). Macrophytes, which greatly differ in their morphology relating to the biometric features of a macrophyte habitat create distinctly different habitat conditions for inhabiting zooplankton. Therefore a spatial differentiation between the aquatic vegetation stands and the open water zone was recorded in the case of species composition and biodiversity index, especially for rotifers. Higher values were found among vegeatated zones which reflects the heterogeneity of a habitat and the availability of ecological niches among most complex macrophyte habitats.

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RÓŻNORODNOŚĆ WROTKÓW I WIOŚLAREK DROBNYCH ZBIORNIKÓW WODNYCH PODLEGAJĄCYCH ZRÓŻNICOWANEJ PRESJI ANTROPOGENICZNEJ NA TERENIE WIELKOPOLSKI

Streszczenie

Artykuł prezentuje wyniki badań parametrów fizyczno-chemicznych wody I ich wpływu na strukturę różnorodności wrotków i skorupiaków, w odniesieniu do struktury taksonomicznej oraz wskaźnika różnorodności gatunkowej ośmiu różniących się od siebie statusem troficznym. Analiza objęła stanowiska bez udziału roślinności (otwarta toń wodna) oraz ze względu na fakt, że w niewielkich oczkach wodnych dno porośnięte jest zazwyczaj przez hydromakrofity również stanowiska zlokalizowane w obrębie różnych typów roślinności wodnej (helofity i elodeidy). Tylko dwa stawy należały do typu mezotroficznego, podczas gdy sześć z nich miało charakter eutroficzny i hipertroficzny. Przeważający wysoki stan trofii był wynikiem zasilania zewnętrznego, pochodzącego z rolniczej zlewni. Analiza udziału % gatunków eutroficznych zooplanktonu wykazała pozytywną zależność ze wskaźnikami trofii oraz z koncentracją chlorofilu a, podczas gdy negatywna zależność stwierdzona została wyłącznie dla wrotków, zasiedlających drobne

śródpolne zbiorniki wodne Wielkopolski o zróżnicowanym stopniu przekształceń antropogenicznych, w relacji do przejrzystości wody. Zwierzęta te wykazały ponadto pozytywną korelację pomiędzy różnorodnością gatunkową a pH, koncentracją tlenu oraz przejrzystością wody, natomiast negatywną zależność pomiędzy liczbą gatunków a przewodnictwem i koncentracją azotu. Wyniki te sugerują, że podwyższenie jakości wód będzie faworyzować występowanie bardziej różnorodnych i stabilnych taksonomicznie zbiorowisk wrotków. Różnorodność Cladocera korelowała pozytywnie tylko z pH, co mogło być wynikiem stosunkowo ubogiej struktury taksonomicznej tej grupy zooplanktonu, niezależnie od warunków troficznych odnoszących się do stopnia antropopresji i degradacji wód stawów w krajobrazie rolniczym. Nawet wzięcie pod uwagę stanowisk zdominowanych przez makrofity nie przyczyniło się do zwiększenia ogólnej wartości wskaźnika Shannon-Wievera w przypadku tej grupy zooplanktonu. W przeciwieństwie do wioślarek, różnorodność gatunkowa wrotków była zdecydowanie większa i różniła się istotnie między poszczególnymi stanowiskami, osiągając najwyższe wartości w najbardziej heterogenicznych siedliskach – elodeidach i helofitach.