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THE IMPACT OF THE ARCHITECTURE OF MACROPHYTES ON THE SPATIAL STRUCTURE OF ZOOPLANKTON OF THE WIELKOWIEJSKIE LAKE

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ABSTRACT. The analysis of the factors, connected with the different features of particular macrophyte species, determining the spatial distribution of zooplankton communities (rotifers and crustaceans) was purpose of this study. Particular zooplankton species reveal habitat preferences, which reflect variability in the spatial structure of particular macrophyte species, which is connected with different shape, length and width of stems.

Key words: *Chara*, crustaceans, macrophytes, rotifers, shallow lake, *Utricularia*

Introduction

Most zooplankton species are typically littoral forms, with only a few species able to adapt to living in open water. It is considered that they are particularly appropriate for habitat analysis because they are able to inhabit a variety of environments (**Pejler** 1995). The analysis of factors determining zooplankton occurrence within the littoral zone of a lake may contribute to the recognition of the diversity of natural zooplankton communities. Water vegetation plays an extremely important role in the structuring of freshwater communities, influencing the interactions between predators and prey and acting as a food source (**Scheffer** 2001). Moreover, different habitat conditions present, providing differences in the suitability for typically littoral and pelagic species and the morphological adaptations of organisms inhabiting particular zones of the lake (**Preissler** 1977) are responsible for zooplankton distribution. Different morphology and spatial structure of the macrophytes influences the amount of the periphyton available for zooplankton. Macrophytes that create a refuge for zooplankton may reduce the predatory effect of planktivourous fish (**Crowder** and **Cooper** 1982). However, less information is available about the allelopathic effect of macrophytes suppressing zooplankton development (**Lauridsen** and **Lodge** 1996) and even less concerning the field data. Animals

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avoid macrophytes probably due to worse conditions within the plant stands compared to the open water (**Pennak** 1973).

Hydromacrophytes differ in cover percentage, density and biomass. Each particular plant differs in shape, length and width of stems. All of these factors structure the zooplankton communities.

This work, considering the impact of differentiated architecture of macrophytes on the spatial distribution of zooplankton communities, was undertaken in order to:

(1) compare the distribution of rotifers and crustaceans among the different species of macrophytes belonging to three types of water vegetation (emerged, floating and submerged),

(2) reveal habitat preferences of particular species of zooplankton,

(3) analyse the structure of littoral species communities' in particular macrophyte zones, differing morphologically and spatially.

Study area

Lake Wielkowiejskie is a shallow lake situated in the western part of the Wielkopolski National Park in the catchment area of the river Warta. It has an area of 13.3 ha, maximum depth of 2.8 m and a mean depth of 1.4 m.

The lake is fully surrounded by a belt of emergent macrophytes with *Typha angustifolia* L. and *Phragmites australis* (Cav.) Steud. Nearly the whole basin is covered by submerged macrophytes, predominately *Nitellopsis obtusa* (Desvaux) Groves, *Chara tomentosa* L., *Ch. hispida* L. and *Utricularia vulgaris* L. Well developed stands of *Nymphaea alba* L. cover around 20% of the water surface.

Methods

The spatial distribution of zooplankton (rotifers and crustaceans) among helophytes, nymphaeids, elodeids, *Chara* meadows and the open water (Fig. 1) was examined at the beginning of August 2000. Samples were taken in triplicate at each site using a plexiglass core sampler (∅ 50 mm). Subsamples, of about 1-L each, were pooled together into a calibrated vessel. The 10-L samples were concentrated using a 45-µm plankton net and were fixed with 4% formalin.

The length of particular plant stems and their biomass adequate to 1 litre of water was estimated. Particular macrophyte matter was taken in triplicate. The results of the plant parameters were the arithmetic mean from the three submeasures. The samples of hydromacrophytes were cut out from a particular area and depth, using a ‘fork-like’ sampler (Bernatowicz sampler; **Bernatowicz** and **Wolny** 1969).

The ANOVA test with the *posteriori* Tukey Test was used for statistical analysis in order to evaluate the differences in density of zooplankton between particular habitats ($N = 18$).

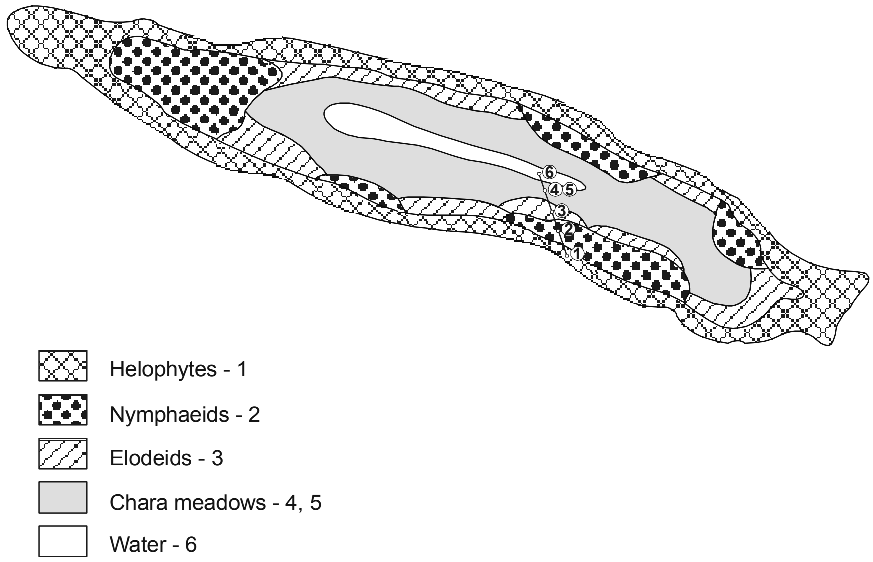

Fig. 1. The map of macrophyte distribution and the sampling stations in Wielkowiejskie lake: 1 – Typha – *Typha angustifolia*/*Phragmites australis*, 2 – N – *Nymphaea alba*, 3 – U – *Utricularia vulgaris*, 4 – Ch h – *Chara hispida*, 5 – Ch t – *Chara tomentosa*, 6 – Water – open water

Ryc. 1. Mapa rozmieszczenia hydromakrofitów i stanowisk badawczych w Jeziorze Wielkowiejskim: 1 – Typha – *Typha angustifolia*/*Phragmites australis*, 2 – N – *Nymphaea alba*, 3 – U – *Utricularia vulgaris*, 4 – Ch h – *Chara hispida*, 5 – Ch t – *Chara tomentosa*, 6 – Water – toń wodna

Results

The macrophyte measures revealed that the stems of *Chara hispida* were the longest and were of the highest biomass in one litre of the lake water. The rush species were characterised by low stem lengths and high stem biomass, which is a result of a very high specific weight, compared to other species. The lowest stem length in one litre of water was observed in *Utricularia*, which was not characterised by the lowest biomass (Table 1).

Altogether 79 species of Rotifera, 28 of Cladocera and 12 of Copepoda were identified from among all the stations. The highest number of zooplankton species were found in the zone of *Nymphaea alba* (76 species). The lowest number of species was observed in the zone of open water (30 species). Macrophyte stands were dominated by littoral species, while at the open water station single littoral species occurred only occasionally. There were not significant changes in the number of zooplankton species between all the macrophyte stations (between 46 species in the *Chara tomentosa* bed to 38 species in the *Ch. hispida* stand for Rotifera; from 13 in the *Utricularia* zone to 25 between *Nymphaea* stand for Cladocera; from 5 in the *Utricularia* stand to 10 in the *Chara tomentosa* bed for Copepoda).

Table 1
The length of particular macrophyte stems and their biomass adequate to 1 litre of water
Długość poszczególnych pędów makrofitów i ich biomasa w 1 litrze wody

Makrophyte Makrofit	Stem length (m) Długość pędu (m)	Stem biomass (g) Biomasa pędu (g)
Typha/Phragmites	1.50	11.05
Chara hispida	10.20	15.53
Chara tomentosa	8.80	6.03
Utricularia	1.70	0.75
Nymphaea	0.25	3.04

The densities of rotifers (F = 13.9442; p = 0.0001) and crustaceans (cladocerans – F = 62.0961; p = 0.0000 and copepods – F = 70.3471; p = 0.0000) differed between all the examined stations. The highest numbers of rotifers were recorded for the beds of *Nymphaea alba* (912 ind·l^{-1}) and *Utricularia vulgaris* (792 ind·l^{-1}) while the lowest among *Typha angustifolia* (231 ind·l^{-1}). At the same time the densities of crustaceans revealed a different pattern with the highest abundance among both species of *Chara* (*Chara tomentosa* – 278 ind·l^{-1}; *Chara hispida* – 664 ind·l^{-1}) and in the *Utricularia* stand (222 ind·l^{-1}) and the lowest in the zones of rushes (55 ind·l^{-1}) and open water (38 ind·l^{-1}) (Fig. 2).

The group of zooplankton species, represented by *Colurella uncinata* (O.F. Müller) (F = 15.1590; p = 0.0000), *Ceriodaphnia pulchella* Sars (F = 9.4182; p = 0.0000), *C. quadrangula* (O.F. Müller) (F = 10.9117; p = 0.0000), *Alonella nana* (Baird) (F = 10.6234; p = 0.0000), *Camptocercus rectirostris* Schoedler (F = 7.5617; p = 0.0000), *Diaphanosoma brachyurum* (Fischer) (F = 14.6814; p = 0.0000), *Acanthocyclops languidoides* (Lilljeborg) (F = 5.1784; p = 0.0004) and *Microcyclops bicolor* (Sars) (F = 8.7790; p = 0.0000) was characterised by high numbers of zooplankton individuals inhabiting both beds of stoneworts (Fig. 3).

The presence of species – *Euchlanis dilatata* (Ehrenberg) (F = 23.1422; p = 0.0000), *Lecane bulla* (Gosse) (F = 17.4097; p = 0.0000), *Acroperus harpae* (Baird) (F = 27.4111; p = 0.0000) and *Sida crystallina* (O.F. Müller) (F = 15.0333; p = 0.0000) was significantly higher in the zone of bladderwort (Fig. 4).

Discussion

The zones of hydromacrophytes in Wielkowiejskie Lake possessed more diverse zooplankton community compared to the open water area. The highest number of zooplankton species appeared within the stand of floating leaves, which differed morphologically from other vegetation beds in the lake. Apart from diverse littoral species community the nymphaeids posses a rich group of pelagic species, which are the result of the transitional character of this zone lying between the open water area and the rest of the macrophyte stands. Zooplankton communities within the particular vegetation zones

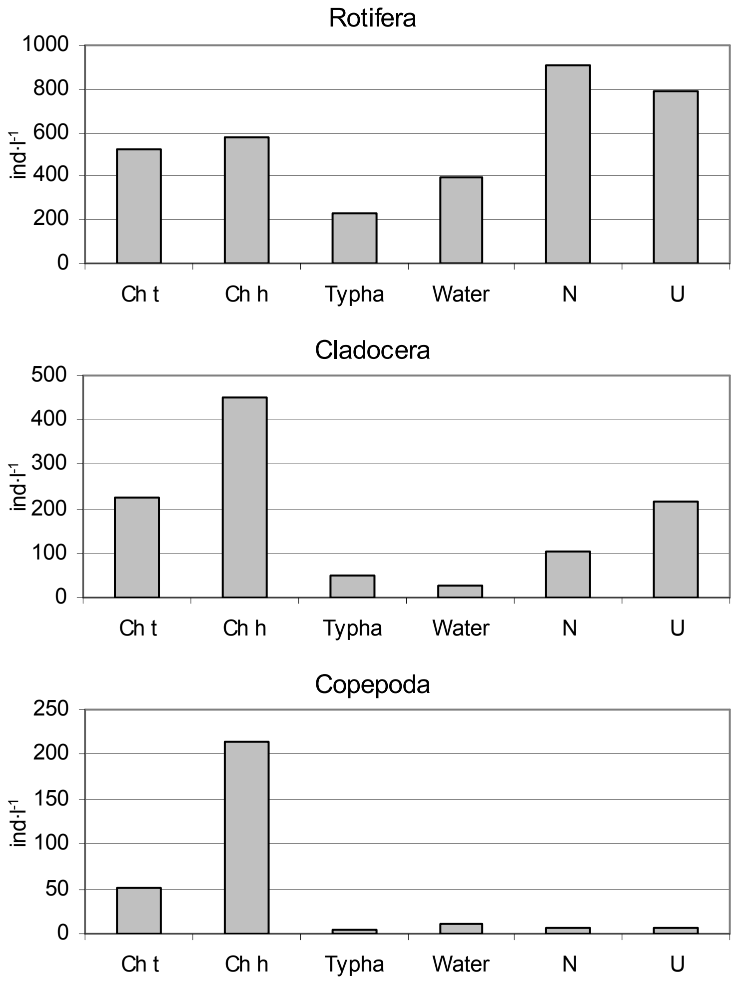

Fig. 2. The numbers of zooplankton in particular zones of Wielkowiejskie lake: Ch t – *Chara tomentosa*, Ch h – *Chara hispida*, Typha – *Typha angustifolia*/*Phragmites australis*, Water – open water, N – *Nymphaea alba*, U – *Utricularia vulgaris*

Ryc. 2. Liczebność zooplanktonu w poszczególnych strefach Jeziora Wielkowiejskiego: Ch t – *Chara tomentosa*, Ch h – *Chara hispida*, Typha – *Typha angustifolia*/*Phragmites australis*, Water – toń wodna, N – *Nymphaea alba*, U – *Utricularia vulgaris*

consist of the epiphytic, benthic as well as numerously pelagic species, which may periodically live in the water vegetation (**Jeppesen** et **al.** 1998).

The numbers of rotifers and crustaceans differed significantly between the examined stations. Both groups of animals revealed discrepancies in their spatial distribution. Rotifers were found to have the highest numbers in the beds of *Nymphaea alba* and *Utricularia vulgaris*, that is in the zones of the lowest biomass of the macrophyte matter. The densities of cladocerans and copepods demonstrated a different pattern with the highest numbers among both species of stoneworts (*Chara tomentosa* and *Ch. hispida*).

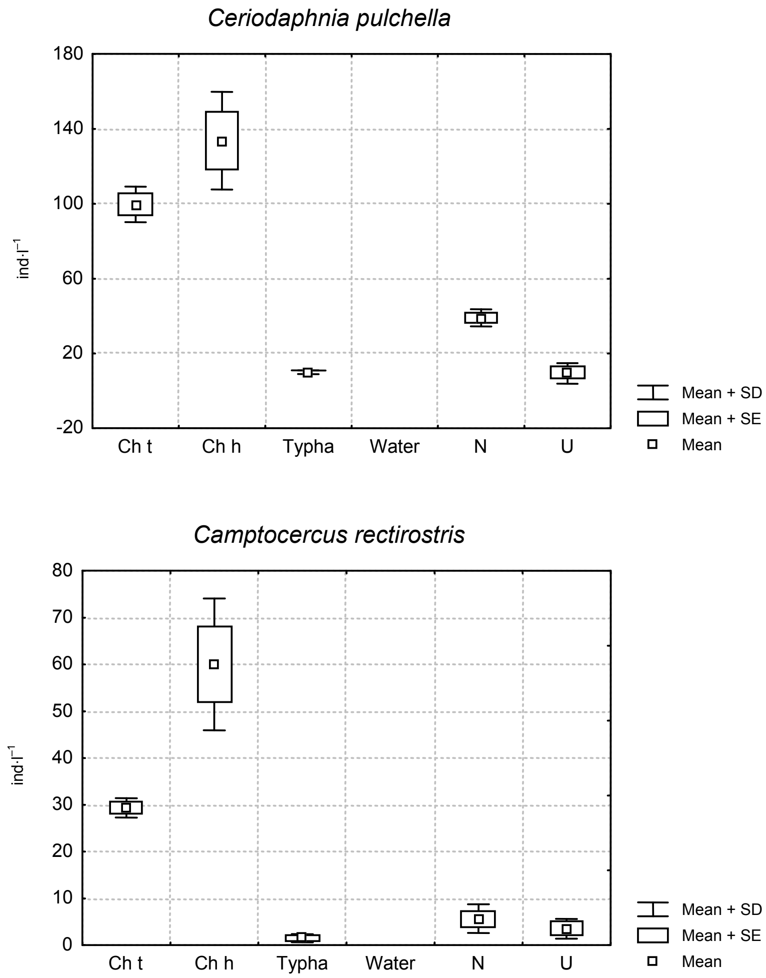

Fig. 3. The numbers of zooplankton species preferring both beds of stoneworts (*Chara tomentosa* and *Ch. hispida*): Ch t – *Chara tomentosa*, Ch h – *Chara hispida*, Typha – *Typha angustifolia*/*Phragmites australis*, Water – open water, N – *Nymphaea alba*, U – *Utricularia vulgaris*

Ryc. 3. Liczebność gatunków zooplanktonu preferujących obie strefy ramienicy (*Chara tomentosa* and *Ch. hispida*): Ch t – *Chara tomentosa*, Ch h – *Chara hispida*, Typha – *Typha angustifolia*/*Phragmites australis*, Water – toń wodna, N – *Nymphaea alba*, U – *Utricularia vulgaris*

The lowest numbers of rotifers and crustaceans were observed in the zones of rushes (consisting of *Typha angustifolia* and *Phragmites australis*), which despite quite a high biomass was characterised by very low stem length. Such a macrophyte bed is not able to provide zooplankton with the spatial complexity, which may result in the low number of niches created by a simply-built plant species and therefore low zooplankton community structure. The differences in the zooplankton communities' distribution within the littoral zone are mostly connected with the density of the macrophyte cover over the

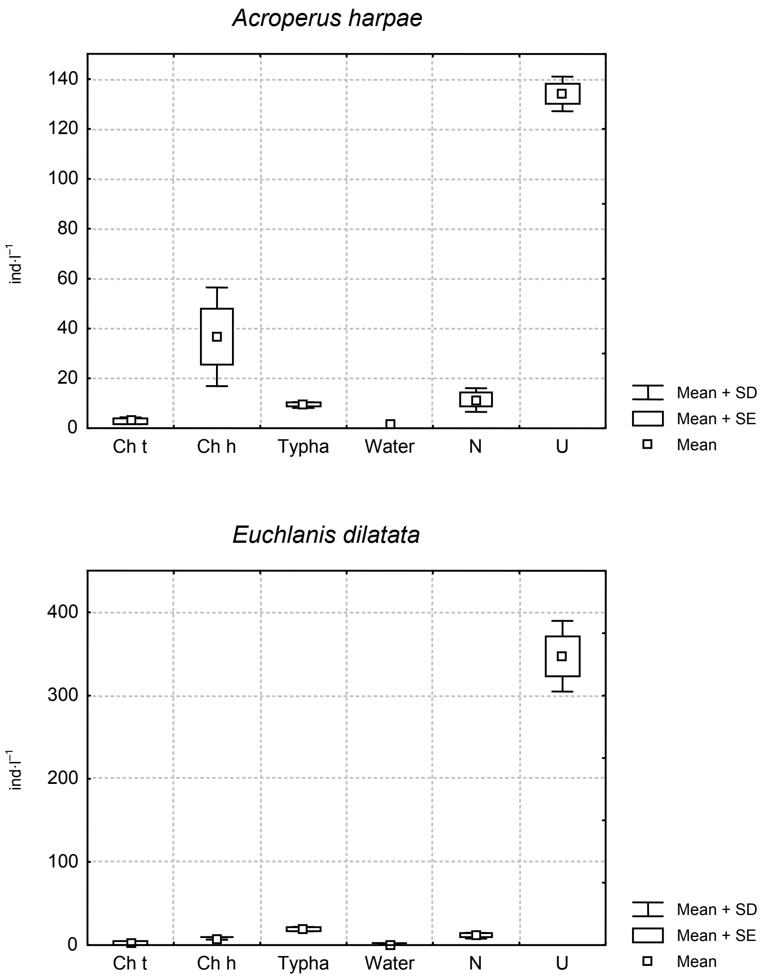

Fig. 4. The numbers of zooplankton species preferring the zone of bladderwort (*Utricularia vulgaris*): Ch t – *Chara tomentosa*, Ch h – *Chara hispida*, Typha – *Typha angustifolia*/*Phragmites australis*, Water – open water, N – *Nymphaea alba*, U – *Utricularia vulgaris*
Ryc. 4. Liczebność gatunków zooplanktonu preferujących strefę pływacza (*Utricularia vulgaris*): Ch t – *Chara tomentosa*, Ch h – *Chara hispida*, Typha – *Typha angustifolia*/*Phragmites australis*, Water – toń wodna, N – *Nymphaea alba*, U – *Utricularia vulgaris*

lake bottom by particular species of macrophytes. **Downing** and **Cyr** (1986) observed that the numbers of invertebrates inhabiting a macrophyte bed depend on the density of the particular plant species. However, **Walsh** (1995) revealed that the thicker and more complicated morphologically the macrophyte bed, the more diverse and more numerous are the zooplankton communities. The above authors also suggested that not all the groups of animals have the same preferences for the same kind of plant and that larger plants with wider leaves, contrary to thick fine-leafed plants like e.g. *Myriophyllum* spp., might be more suitable for heavier and crawling invertebrates. Another important aspects are the food base, consisting of planktonic algae, periphyton, detritus and bacteria (**Gons** 1979, **Theil-Nielsen** and **Søndergaard** 1999) and the role of predation, which is responsible for the zooplankton escape from the open water into the littoral (**Timms** and **Moss** 1984, **Lauridsen** et **al.** 1996).

In lake Wielkowiejskie differentiated habitat preferences (considering different macrophyte types) of particular zooplankton species were observed. There were two groups of habitats (both zones of *Chara* and *Utricularia* stand) distinguished. Various factors responsible for creating optimal conditions for living should be considered, when analysing the associations between the occurrence of animals and particular habitat. Physical elements e.g. temperature, tolerance to changes of chemical environment and also exploitative competition for the shared food resources between particular organisms (**Rozenzweig** 1991, **Sarma** et **al.** 1996), as well as predator vulnerability (**Pejler** and **Bērziņš** 1989) are among such factors. Morphological structure and the density of macrophytes also affect the creation of specific zooplankton communities within particular vegetation stands. **Gliwicz** and **Rybak** (1976) hypothesise that the denser the macrophyte stand, the more isolated the open water within the stand and therefore the more ‘distinct’ zooplankton communities in such a habitat. It seems also very probable that in many cases the factor responsible for the preferences of organisms to particular habitats are the allelopathic effects of the macrophyte species, which are inhabited less ‘willingly’ in this case. This phenomenon is still not fully recognised, although there are some data considering such an effect (**Burns** and **Dodds** 1999).

The main factor determining the distribution of zooplankton communities in Wielkowiejskie lake seems to be the architecture, which is understood as the morphological and spatial structure of particular phytocoenosis.

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WPŁYW „ARCHITEKTURY" MAKROFITÓW NA STRUKTURĘ PRZESTRZENNĄ ZOOPLANKTONU JEZIORA WIELKOWIEJSKIEGO

S t r e s z c z e n i e

Celem pracy była analiza czynników związanych ze zróżnicowaną biometrią poszczególnych gatunków makrofitów, wpływających na przestrzenne rozmieszczenie zespołów zooplanktonu (wrotków i skorupiaków). Poszczególne gatunki zooplanktonu wykazywały preferencje siedliskowe będące wynikiem różnorodności w strukturze przestrzennej i morfologicznej poszczególnych gatunków roślin. Komplikacja architektoniczna makrofitów jest związana z różnym kształtem, długością i szerokością pędów.