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Relationship between plankton assemblages and habitat characteristics of stands of *Typha angustifolia* and *Chara hispida* in Lake Wielkowiejskie

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Abstract

The results of investigations performed in Lake Wielkowiejskie showed the influence of macrophyte architecture, understood as plant density, on the structure of plankton communities as well as the habitat preferences of particular species in both seasonal and spatial aspects.

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INTRODUCTION

Littoral zones of lakes contribute to the structuring of freshwater communities through interactions between predators and prey and providing food resources (Jeppesen et al. 1998). Particular macrophyte species have different architectures as a result of varied stem length or biomass per lake unit. The morphology of plant habitats affects the structure of plant or animal assemblages associated with aquatic plants (Dvořák 1987, Scheffer 2001). It has been demonstrated that various plant species support various epiphytic communities (Blindow 1987), which, in turn, impacts zooplankton communities in littoral zones since periphyton, along with protozoans, bacteria and detritus, can serve as an indirect food source for zooplankton (Theil-Nielsen, Søndergaard 1999). Moreover, plankton numbers are often positively correlated with the density of macrophyte beds in the presence of fish in lakes (Kuczyńska-Kippen, Nagengast 2003; Kuczyńska-Kippen 2005; Kuczyńska-Kippen, Nagengast 2006). Another factor that should be taken into consideration when analyzing plankton communities inhabiting the littoral area of lakes are seasonal changes in the macrophyte habitats related to the varied growth of the particular plant parts.

The structure and dynamics of plankton communities can be mediated by a number of environmental parameters (Rosenzweig 1991; Theil-Nielsen, Søndergaard 1999) including physical (including the structure of an aquatic plant bed), chemical, or biological. Aquatic stands offer zooplankton concealment from both vertebrate and invertebrate predators (Jeppesen et al. 1998).

Thus, the aim of the current study was to determine whether the physical and chemical parameters of the macrophyte habitat had an impact on plankton communities within the *Typha* and *Chara* stands in Lake Wielkowiejskie. Moreover, an attempt was made to identify the particular habitat preferences of plankton species.

MATERIALS AND METHODS

The investigation was conducted in Lake Wielkowiejskie, which is a shallow, macrophyte-dominated water body. It is situated in the Wielkopolski National Park and has an area of 13.3 ha, maximum depth of 2.8 m, and a mean depth of 1.4 m (Jańczak et al. 1996). Lake Wielkowiejskie is a macrophyte-dominated water body with a full sequence of rush and water vegetation zonation (Nagengast, Pełechaty 2001). The helophytes are comprised of three communities: *Phragmitetum communis* (Koch 1926) Schmale 1939, *Typhetum angustifoliae* Soó 1927, and *Thelypteridi-Phragmitetum* Kuiper 1958; the nymphaeids by *Nupharo-Nymphaeetum albae* Tomaszewicz 1997; the elodeids by *Myriophylletum verticillati* Soó 1927; pleustophytes by *Lemno-Spirodeletum* W. Koch 1954, *Lemno-Utricularietum vulgaris* Soó 1928, and *Hydrocharitetum morsus ranae* Lang. 1935; and finally, charophytes by *Charetum hispidae* Sauer 1937 ex Krausch 1964, *Charetum tomentosae* Corillion 1957, and *Nitellopsidetum obtusae* (Sauer 1937) Dąmbska 1961.

The examination of the spatial distribution of plankton in the phytocoenoses of Typha and Chara and, for the sake of comparison, in open water stands was conducted in 2003 in the spring, summer, and autumn seasons. Plankton samples were taken in triplicate using a plexiglass core sampler (∅ 50 mm). The 10 l samples of zooplankton were concentrated using a 45-μm plankton net and fixed with 4% formalin. Phytoplankton composition was determined from sedimented samples with light microscopy, and taxa abundance was counted using a Fuchs-Rosenthal chamber. The phytoplankton biomass was estimated from cell and filament numbers and their specific volumes (Kawecka, Eloranta 1994). Information regarding the number of taxa, abundance, and biomass of phytoplankton at the sampling stations in Lake Wielkowiejskie were presented in detail in Celewicz et al. (2004). The plant material was cut from a known area and depth. The length of particular macrophyte stems and their biomass equal to 1 l of water were estimated. Samples of plant matter were collected in triplicate.

The T-Student test was used for statistical analysis to evaluate the differences in density of phytoplankton and zooplankton between the three habitats examined (N=27). The U-Mann test was used for analyzing the differences in the density and biomass of particular macrophyte habitats (N=18). The similarity between zooplankton communities in different habitats was compared using the Ward method and the Euclidean distance measure (Sokal 1961). Similarity is presented in graphic form with a tree diagram (Krebs 1989).

RESULTS AND DISCUSSION

The results of physicochemical analysis indicate that Lake Wielkowiejskie is weakly eutrophic. In three subsequent seasons, the highest concentrations of nitrogen and phosphorus were noted in the macrophyte zones relative to the unvegetated area. The comparison of the results obtained from the open water zone with earlier data (Siepak 2001) indicated that the concentration of nitrogen in 2003 was considerably lower than in 1997, while concentrations of phosphorus remained at the same level (Celewicz et al. 2004; Kuczyńska-Kippen, Nagengast 2006).

The statistical analysis revealed significant differences only in the length of plant stems between the two macrophyte species examined (Z=3.576, p=0.00035), while differences in biomass were insignificant. This indicates considerable differentiation in plant density between the stoneworts and bulrushes. The stems of the bulrush (particularly the submerged parts) have a great biomass but they grow sparsely, as opposed to stoneworts, which grow densely but single specimens have very small biomass. The number of specimens in this case compensates for the low biomass compared to bulrushes. Therefore, in the same volume of water, differences in the biomass of the two macrophyte species examined are insignificant. In Lake Wielkowiejskie, *Chara hispida* creates dense and compact submerged beds, while there are only a few specimens of *Typha angustifolia* per m^2.

The current investigation focused on the spatial and seasonal analysis of phyto- and zooplankton communities in relation to architecturally different macrophytes and in comparison to the open water zone.

The phytoplankton of the investigated water body was of a green-diatom-cyanobacterial character, which is often found in eutrophic lakes (Dąmbska et al. 1981; Cerbin and Kokociński 1998). The presence of 91 taxa of procaryotic and eucaryotic algae, belonging to 7 systematic groups (Chlorophyta – 42, Bacillariophyceae – 26, Cyanoprokaryota – 12, Cryptophyceae – 5, Dinophyceae – 3, Euglenophyta – 2, Chrysophyceae – 1) was recorded. The taxonomical participation of particular systematic groups was similar at all the sampling stations. The richest community was found in the stonewort stand (Celewicz et al. 2004). Numerous papers (e.g. Kuczyńska-Kippen, Messyasz 1998; Celewicz, Messyasz 2000; Celewicz et al. 2001) have reported that a compact stand of macrophytes can create a specific habitat and can contribute to an increase in plankton species diversity.

Moreover, the total abundance and biomass of phytoplankton (from all the investigated samples) reached the highest values in the stonewort stands (13175 ind. ml^{-1} 178.61 mg ml^{-1}, respectively). This was probably connected with the dominance of the plankton by taxa of periphytic communities (diatoms of the genus *Cymbella*, *Fragilaria*, *Epithemia*, *Cocconeis*, and *Gomphonema*), which must have become unattached due to wavy motion. The dominance of diatoms (1025 ind. ml^{-1} and 1950 ind. ml^{-1} respectively) was noted in the spring and autumn at this station, while in the summer the dominant was green algae (mainly *Spirogyra* sp., a littoral-associated form; 5175 ind. ml^{-1}), the occurrence of which is connected with water nutrient enrichment (Kawecka, Eloranta 1994). In the rush and open water zones, cryptomonads prevailed in the spring (1550 ind. ml^{-1} and 2700 ind. ml^{-1} respectively), while green algae did so in the autumn (625 ind. ml^{-1} and 425 ind. ml^{-1} respectively). High densities of cryptomonads in the spring indicate that conditions were changeable and unstable due to the water mixing period in shallow lakes (Burchardt, Messyasz 2004). Moreover, species of the genus *Cryptomonas* develop in shallow lakes profusely at low water temperatures (Starmach 1974). In the summer season differences in the quantity dominance of particular phytoplankton groups between rushes and the open water area were observed. In the rushes diatom dominance was recorded (425 ind. ml^{-1}), while in the pelagic zone, the dominants were chrysophytes (1950 ind. ml^{-1}). The high abundance of the chrysophyte *Dinobryon divergens* Imhoff may indicate the unstable eutrophic condition of the investigated lake, because the most optimal conditions for the development of chrysophytes are clean waters with low nutrient concentrations (Büsing 1998, Domaizon et al. 2003, Vrba et al. 2003).

Statistical analysis did not reveal significant differences between habitats or seasons investigated within particular systematic groups of algae. However, significant differences between particular zones were found for three species: *Fragilaria ulna* var. *acus* (Kützing) Lange-Bertalot ($t = -2.99$, $p < 0.05$); *Cosmarium laeve* Rabenhorst ($t = -3.21$, $p < 0.05$); *Pediastrum tetras* (Ehrenberg) Ralfs ($t = -3.99$, $p < 0.05$), as well as between particular seasons: *Fragilaria ulna* (Nitzsch) Lange-Bert. ($t = 3.99$, $p < 0.05$); *Cryptomonas ovata* Ehrenberg ($t = 3.09$, $p < 0.05$).

The zooplankton community of Lake Wielkowiejskie was dominated by rotifers both taxonomically and in abundance. A total of 134 zooplankton species (89 Rotifera, 32 Cladocera, 13 Copepoda) were identified, and macrophyte zones were characterized by a more diverse species structure than was the open water area. The highest values of zooplankton communities were observed in the *Chara* bed, where mean densities reached 2367 ind. l^{-1} (Celewicz et al. 2004). The diversity of the water organism populations of the phytolittoral area is modified by a number of factors including physicochemical features of the habitat as well as biological interactions between particular segments of the biocoenosis (Leibold 1991, Rosenzweig 1991). However, zooplankton often uses dense macrophyte habitats as a source of food as well as refuge from predators; thus it gathers there in higher numbers during the daytime (Gliwicz, Rybak 1976; Wallace 1980; Paterson 1993; Moss et al. 1998).

The analysis of zooplankton similarity among the zones and seasons in Lake Wielkowiejskie revealed that the strongest relations among sampling stations were noted with regard to crustaceans. Although not as extensive, a similar grouping was noted with regard to rotifers (Fig 1.). Similar results with regard to periphytic communities gathering in particular habitats have also been reported (Messyasz, Kuczyńska-Kippen 2006).

Some zooplankton species in temperate climates are of cosmopolitan distribution and can occur irrespective of season, while others are restricted to

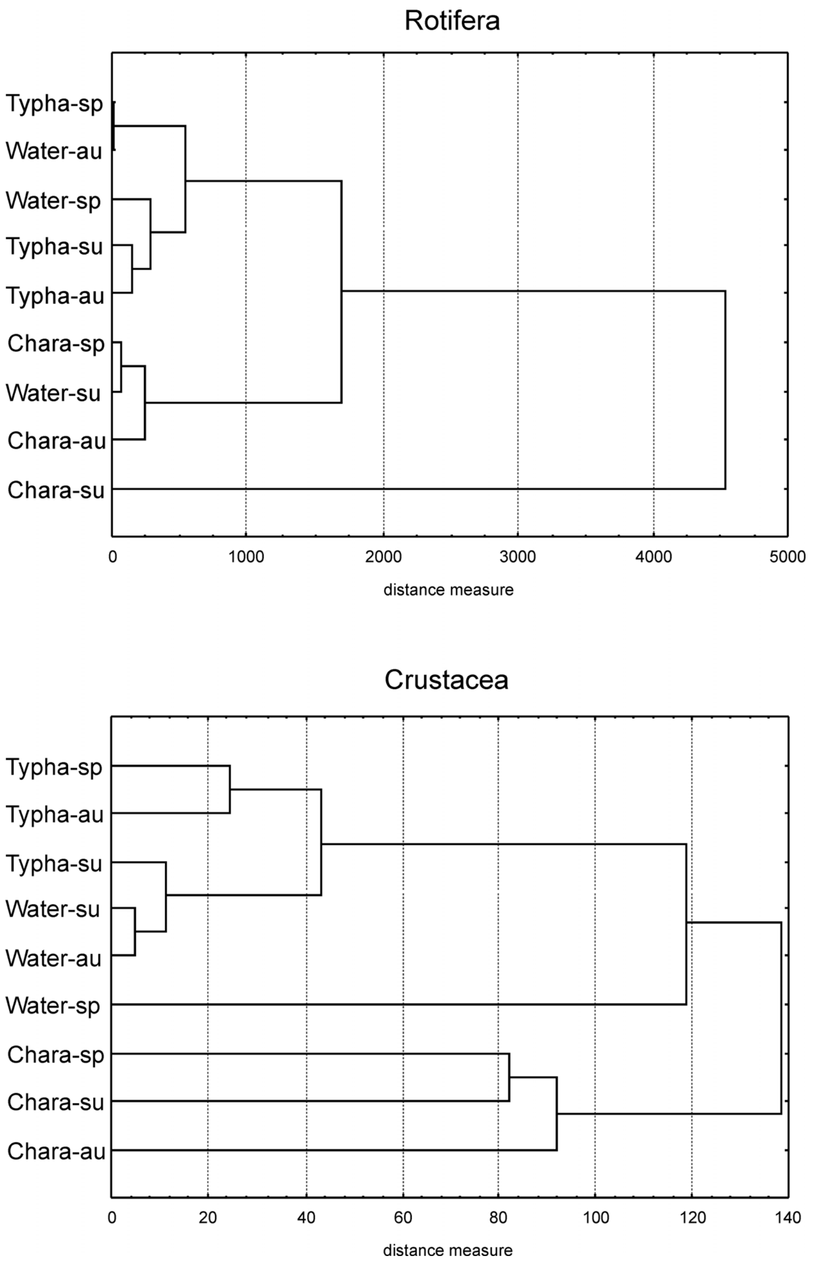

Fig. 1. The average value of rotifer and crustacean community similarity in all the examined lakes and seasons (the Ward method and Euclidean distance measure)(sp – spring, su – summer, au – autumn).

particular times of year or particular water bodies, particular zones of a lake, or even particular macrophyte species (Pennak 1966, Lair 1990, Jose-de-Paggi 1993). In Lake Wielkowiejskie, there was a group of species that selected particular zones of the lake as well as a group whose numbers were restricted to a particular season. Statistical analysis revealed significant differences only in the case of total copepod densities ($t = 2.153$, $p < 0.05$) among the sampling stations. There were 16 zooplankton species in total associated with particular habitat types independent of season. Most taxa (12) were *Chara*-associated, as follows: *Bdelloidae*: $t = 6.320$, $p < 0.01$; *Colurella adriatica* Ehrenberg: $t = 3.106$, $p < 0.01$; *Colurella uncinata* (Müller): $t = 4.104$, $p < 0.01$; *Lecane luna* (Müller): $t = 4.072$, $p < 0.01$; *Lecane lunaris* (Ehrenberg): $t = 3.487$, $p < 0.01$; *Lepadella triptera* Ehrenberg: $t = 2.485$, $p < 0.05$; *Testudinella parva* (Ternetz): $t = 6.161$, $p < 0.01$; *T. parva* f. *bidentata* (Ternetz): $t = 3.015$, $p < 0.01$; *Trichotria tetractis* (Ehrenberg): $t = 5.091$, $p < 0.01$; *Acroperus harpae* (Baird): $t = 4.087$, $p < 0.01$; *Alonella nana* (Baird): $t = 2.286$, $p < 0.05$; *Ceriodaphnia quadrangula* (O.F. Müller): $t = -3.181$, $p < 0.01$). Two species were characteristic of the unvegetated zone (*Keratella cochlearis* (Gosse): $t = -2.979$, $p < 0.01$; *Polyarthra remata* (Skorikov): $t = -2.162$, $p < 0.05$), while two species exhibited preferences for both *Chara* and *Typha* stands (*Euchlanis dilatata* Ehrenberg: $t = 2.723$, $p < 0.05$; *Lecane closterocerca* Schmarda: $t = 2.578$, $p < 0.05$). These preferences for particular species were probably due to the shallowness of the lake, the direct contact between the rush and stonewort zones, as well as the small areas of the unvegetated zone. Moreover, six species revealed statistically higher densities in particular seasons, where *Keratella quadrata* (O.F. Müller) ($t = 2.328$, $p < 0.05$), *P. remata* ($t = 3.118$, $p < 0.01$), *Bosmina coregoni* (O.F. Müller) ($t = 3.065$, $p < 0.01$), and *B. longirostris* Baird ($t = 3.748$, $p < 0.01$) occurred in much higher numbers in the spring, while *L. closterocerca* ($t = -2.619$, $p < 0.05$) and *P. major* Burckhardt ($t = -2.582$, $p < 0.05$) were more numerous in the summer.

Most species chose the *Chara* bed most selectively, which might have been the result of the stonewort having the most spatially complicated structure due to its stem length being the longest per lake volume unit. It seems probable that among the factors determining the zooplankton communities within the littoral zone of Lake Wielkowiejskie, among the most important are the morphological and spatial structure of particular macrophyte species. It is expected that the zooplankton communities differ greatly between various macrophyte stands that differ with regard to physical parameters including cover percentage, density, and biomass (Canfield et al. 1984, Scheffer 2001).

The study of the plankton community structure in two macrophyte stands revealed that aquatic plant habitat, understood as plant density and biomass, had a strong impact on this community, which suggests that higher degrees of habitat heterogeneity provide more favorable life conditions for phyto- and zooplankton organisms.

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