The impact of biometric parameters of a hydromacrophyte habitat on the structure of zooplankton communities in various types of small water bodies

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Abstract

Hydromacrophyte habitats, which can differ in a multiplicity of biometric parameters, are among the most important factors affecting zooplankton community structure. The main goal of this work was to determine the impact of plant habitat parameters expressed by density, biomass, and plant volume along with chemical features on the composition and dynamics of rotifer and crustacean communities.

A number of small water bodies of different origin (12) located in different catchment areas of the Wielkopolska region were analyzed.

It was found that helophytes and nymphaeids had the highest biomass and the lowest stem density, while elodeids were of the lowest biomass and the greatest stem density. Similarity analysis confirmed this distribution of biometric parameters among particular ecological groups of macrophytes.

The greatest numbers of zooplankton were noted among vegetated zones, which supports the idea of zooplankton using macrophytes as anti-predator refuge. Based on the study of a total of 23 plant stands, it was found that macrophyte biomass and the density of the plant habitat were the strongest predictors of three biometric parameters of zooplankton abundance.
INTRODUCTION

The functioning of small water bodies depends on a variety of environmental elements which influence the creation of specific plankton communities. One of the crucial factors affecting the structure of a zooplankton community is the hydromacrophyte habitat, which can differ in stand density (stated as the stem length per 1 liter of water), biomass (dry mass l\(^{-1}\)) and volume (infested volume l\(^{-1}\)), the percent of macrophyte cover, and the morphological build of particular plant species. Zooplankton communities may differ greatly between differentiated macrophyte stands, which, in turn, differ in physical parameters (Canfield et al. 1984). The biomass of certain species of plant relates both to their ability to grow to the water surface and to the season, since this also affects macrophyte development.

The increase in plankton densities in the littoral zone is mediated by different environmental factors (Leibold 1991), including the presence of vegetated beds. Zooplankton seek refuge from predators, both vertebrate or invertebrate, among macrophyte-dominated areas (Timms and Moss 1984, Moss et al. 1998). When the pressure of vertebrate predation is particularly high, most zooplankton communities gather in vegetated areas during the daylight hours (Rybak and Wygleńska 2003). However, in nature a combination of different predators will normally occur and effectiveness in prey-capture can depend largely on increased plant complexity (Van de Meutter et al. 2005).

Moreover, macrophyte stands can provide both rotifers and crustaceans with a nutritional food base which consists of the algae present in the spaces filling the plant stems, accompanied by great amounts of detritus, bacteria, or protozoans (Theil-Nielsen and Søndergaard 1999). In addition, some zooplankton taxa can feed easily on periphytic communities (Gons 1979). The structure of periphytic assemblages can also relate to the morphology of the plant habitat. The phenomenon of the impact of expanding macrophyte biomass and density through the enlargement of the possible substrata surface on the increase of the total periphyton biomass is well known (Pieczyńska 1976).

The main goal of this work was to determine the impact that the hydromacrophyte habitat parameters expressed by density, biomass and plant volume had on the composition and dynamics of rotifer and crustacean communities.

MATERIALS AND METHODS

Twelve small water bodies of different origin and in different catchment areas and located in the Wielkopolska region (mid western Poland) were analyzed. The water bodies consisted of typical mid forest ponds (nos. 10 – 12),
strongly anthropogenically modified ponds in urban landscapes (nos. 4 – 6), strongly anthropogenically modified ponds in agricultural areas (nos. 7 – 9), and three clay-pit ponds (nos. 1 – 3). Among the chosen ponds, only two (nos. 10 and 11) were connected by a water channel, while the remaining ones had no inflow or outflow. In the summer season, within chosen water and rush vegetation and in the open water, an inventory of vegetation and a collection of water samples for zooplankton and chemical analysis were taken as well as measurements of physical parameters. In order to determine the biometric features of macrophytes, plants were cut, measured, dried and weighed, and the results obtained were estimated per 1 liter of water. In the case of *Myriophyllum spicatum, Potamogeton lucens, P. pectinatus, Ceratophyllum demersum, Batrachium circinatum,* and *Zannichellia palustris,* length was understood as the main stem with leaves. Branches of subsequent orders were treated as separated stems. The underwater *Typha latifolia, Phragmites australis,* and *Schoenoplectus lacustris* stems together with adherent leaves were treated as a single length unit. The length of the *Polygonum amphibium* and *Potamogeton natans* stems was equal to the length of its petiole. The plant material was cut from a known area and depth. The length of a particular macrophyte stems and the biomass equivalent to 1 liter of water were estimated. Particular plant matter samples were taken in triplicate.

Zooplankton was sampled with a plexiglass core sampler (Ø50 mm). Plankton samples and plant matter samples were also taken in triplicate.

The Kruskal-Wallis test was applied for statistical analysis in order to evaluate the differences in macrophyte measures between particular ecological types (N=69).

The similarities between biometric macrophyte variables in different habitats of the examined water bodies were compared using Euclidean distance as a distance measure and the single linkage method as an amalgamation rule to determine when two clusters are sufficiently similar to be linked together. The graphic form of the similarity is presented in a hierarchical cluster tree.

The relationship between biometric macrophyte variables and the numbers of zooplankton communities was verified with the Pearson correlation (p<0.05).

**RESULTS**

On analyzing the biometric parameters, it was found that macrophytes at pond nos. 7 and 12 were characterized by the highest stem length. The lowest values were obtained at water bodies nos. 3, 5, and 6, which had, at the same time, the greatest biomass. Particular plant species had a decisive influence on the results. In pond nos. 7 and 12 elodeids prevailed with dominating species such as *Zannichellia palustris* and *Potamogeton pectinatus,* while in water
bodies nos. 3, 5 and 6 helophytes, with the dominating macrophyte species *Phragmites australis*, were the most abundant.

Comparing each separated plant community grouped into ecological types (nymphaeids, helophytes, and elodeids), statistically significant differences were found in the case of macrophyte density ($H_{2,69}=38.3421; p<0.01$) and biomass ($H_{2,69}=27.9738; p<0.01$). Plant density was the highest in the case of submerged macrophytes, while both floating leaved and rush emerged vegetation were of much lower plant stem density (Fig. 1). The comparison of certain macrophyte associations indicated that the greatest density was characteristic for stands of *Zannichellietum palustris*, then the remaining species of elodeids, and the lowest was noted for helophytes and nymphaeids (Fig. 2). A similar distribution among particular ecological groups of macrophytes was confirmed by comparing the similarity analysis using the single linkage method and the Euclidean distance measure, which distinguished three groups of phytocoenosis in relation to plant length (Fig. 3). The first group was composed of all the stations with *Typha latifolia*, the second of all the submerged species, and the third one grouped the rush and floating leaf vegetation.

However, it was found that helophytes and then nymphaeids were of the significantly highest biomass, while elodeids were of the lowest (Fig. 1). The analysis of particular macrophyte species indicated that the greatest biomass was characteristic for beds of *Polygonum amphibium* and *Phragmites australis* and the lowest for *Zannichellia palustris* (Fig. 2).

Comparing zooplankton abundance between the open water and macrophyte stands it was noted that the greatest numbers were always recorded for the vegetated zones.

Based on the examination of 23 vegetated stations at the 12 small water bodies, it was clear that, of the three biometric parameters, macrophyte biomass and the density of the plant habitats were the strongest predictors of zooplankton abundance. A positive relationship was found between densities of Rotifera ($r = 0.3267; p<0.01$) and Cladocera ($r = 0.3282; p<0.01$) and the biomass of hydromacrophytes as well as between the densities of plant stems and the abundance of Copepoda ($r = 0.2577; p<0.05$). Moreover, most species (17 - 11 rotifers and 6 crustaceans) correlated significantly with plant biomass (only in the case of *Colurella uncinata* was there a negative relationship). Another three species (1 and 2, respectively) revealed a positive correlation with plant stem length (Table 1).
Fig. 1. Stem length (m l⁻¹) and stem biomass (g l⁻¹) in one liter of lake water between particular aquatic plant groups (nymph – nymphaeids; heloph – helophytes; elod – elodeids).
Fig. 2. Stem length (m l⁻¹) and stem biomass (g l⁻¹) in one liter of lake water between particular aquatic plant communities (Phr – Phragmitetum communis; Zann – Zannichellietum palustris; Ppect – Potametum pectinati; Myrio – Myriophylletum spicatum; Pluc – Potametum lucentis; Batr – Ranunculetum circinati; Sch – Scirpetum lacustris; Pnat – Potametum natantis; Cerat – Ceratophylletum demersi; Typha – Typhetum latifoliae; Polyg – Polygonetum natantis).
Table 1

The correlation between the densities of particular zooplankton species and macrophyte parameters (stem length or biomass).

<table>
<thead>
<tr>
<th>Species</th>
<th>Parameter</th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyarthra vulgaris Carlin</td>
<td>length</td>
<td>0.4128</td>
<td>0.000</td>
</tr>
<tr>
<td>Asplanchna priodonta Gosse</td>
<td>biomass</td>
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<tr>
<td>Brachionus angularis (Gosse)</td>
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<td>0.3815</td>
<td>0.001</td>
</tr>
<tr>
<td>Keratella cochlearis (Gosse)</td>
<td>biomass</td>
<td>0.3841</td>
<td>0.001</td>
</tr>
<tr>
<td>Keratella quadrata (O.F. Müller)</td>
<td>biomass</td>
<td>0.3755</td>
<td>0.001</td>
</tr>
<tr>
<td>Filinia longiseta (Ehrenberg)</td>
<td>biomass</td>
<td>0.3719</td>
<td>0.002</td>
</tr>
<tr>
<td>Trichocerca cylindrica (Imhof)</td>
<td>biomass</td>
<td>0.3591</td>
<td>0.002</td>
</tr>
<tr>
<td>Cephalodella tinca Wulfert</td>
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<td>0.3507</td>
<td>0.003</td>
</tr>
<tr>
<td>Collotheca mutabilis (Hudson)</td>
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</tr>
<tr>
<td>Trichocerca pusilla (Jennings)</td>
<td>biomass</td>
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</tr>
<tr>
<td>Trichocerca similis (Wierzejski)</td>
<td>biomass</td>
<td>0.2825</td>
<td>0.019</td>
</tr>
<tr>
<td>Colurella uncinata (O.F. Müller)</td>
<td>biomass</td>
<td>-0.2665</td>
<td>0.027</td>
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Crustacea

<table>
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<th>Species</th>
<th>Parameter</th>
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<th>p</th>
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<tr>
<td>Ceriodaphnia pulchella Sars</td>
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<td>0.5358</td>
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</tr>
<tr>
<td>Camptocercus rectirostris Schoedler</td>
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<tr>
<td>Euryercus lammelatus (O.F. Müller)</td>
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<tr>
<td>Thermocyclops othonoides Sars</td>
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<tr>
<td>Bosmina longirostris (O.F. Müller)</td>
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</tr>
<tr>
<td>Simocephalus expinosus (Koch)</td>
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<tr>
<td>Ceriodaphnia quadrangula (O.F. Müller)</td>
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<tr>
<td>Bosmina coregoni Baird</td>
<td>biomass</td>
<td>0.2920</td>
<td>0.015</td>
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</tbody>
</table>

Fig. 3. Mean similarity coefficient of stem length (m l⁻¹) in one liter of lake water of aquatic plant communities in the water bodies studied (Euclidean distance measure; Single linkage method) (legend see Fig. 2).
DISCUSSION

The variation in the zooplankton structure on different macrophyte species may be due to differentiated environmental factors, including the specific architecture of aquatic plant stands which relates to the physical parameters of a particular macrophyte substrate, seasonality, physicochemical parameters as well as biotic relations (Duggan 2001). The comparison of the biometric measurements of macrophyte communities (grouped in three ecological types) of the 12 examined water bodies studied indicated that there were significant differences in the case of plant density and biomass. Only in the case of the volume of the plant stems per particular pond water unit were the differences not significant, which may confirm earlier findings (Kuczyńska-Kippen and Nagengast 2006) that plant biomass and density are of the greatest importance in evaluating the heterogeneity of macrophyte architecture.

The results of the current study based on the biometric parameters of all the plant species confirmed the anticipated assumptions. Elodeids had the longest stem length and created dense, compact beds (Kłosowski and Kłosowski 2001). They were characterized by the greatest density because their stems are flexible with a multiplicity of air chambers with weakly (if at all) developed mechanical tissues (Szweykowska and Szweykowski 2005). The comparison of particular macrophyte communities revealed that the greatest density was characteristic for stands dominated by horned-pondweed (*Zannichellia palustris*), which forms dense beds owing to the character of its very thin, narrow leaves that are often highly dissected and very flexible (Sculthorpe 1967). At the same time, submerged macrophyte species were of the lowest biomass. Contrary to the distribution of biometric parameters observed in the group of elodeids, the helophytes had heavier stems, and, since they had the lowest stem densities, they were characterized by the highest biomass. The similarity analysis confirmed the emergence of three groups of phytocoenosis in relation to plant length. All the stations of helophytes with *Typha latifolia* were grouped together. The second group had all the elodeid species and the third one was comprised of rush and floating leaf vegetation.

On analyzing each community separately, it was found that *Polygonetum natantis* (nymphaeid community) was an exception as it possessed the highest biomass. This was probably due to the high biomass of the leaves of *Polygonum amphibium f. natans*, which, in the water bodies studied, had very dense foliage. The leaves of nymphaeids are usually broader and are firm or leathery but flexible enough to resist tearing by wave action (Sculthorpe 1967).

The comparison of the biometric parameters between particular water bodies indicated that the macrophytes of two ponds, nos. 7 and 12, were characterized by the highest stem length. In both ponds submerged species
prevailed with macrophytes with very long, thin, highly dissected leaves. In contrast, *Zannichellia palustris* has linear leaves and both the leaves and stems of this plant species are thread-like. Another species, *Potamogeton pectinatus*, is characterized by long, slender, thread-like stems, which branch. The submerged leaves of sago pondweed are quite narrow and slender. The lowest values of stem length were obtained at pond nos. 3, 5, and 6, which all had at the same time the greatest biomass. The particular plant species had a decisive influence on the results obtained. In these three ponds helophytes with dominating *Phragmites australis* were the most abundant. The common reed is characterized by its stiff stems owing to the high content of cellulose and silica. It has horizontal stems, which are also smooth, round, and unbranched. The underwater stems of this macrophyte species are often almost woody, which can contribute to its high biomass.

Zooplankton densities were always much higher in the vegetated zones than in the open water area of all the ponds studied, which reflects their anti-predator refuge role.

A subject of further investigation is the preferences of particular zooplankton species for studied parameters of the macrophytes. Biomass and the density of the macrophyte habitat were the strongest predictors of zooplankton densities. A positive correlation was found between the abundance of Rotifera and Cladocera and the biomass of macrophytes as well as between the densities of plant stems and the numbers of Copepoda. Similar results were obtained by other authors (e.g., Cheruvelil et al. 2002, Scheffer 2001), who noted that zooplankton communities often differ among macrophyte habitats, which differ in their plant architecture relating to cover percentage, density, biomass, or in chemical factors (Conde-Porcuna 2000). Moreover, van den Berg et al. (1997) proved that the biomass of a plant strongly predicts the differentiation of macrozoobenthos communities within the littoral zone.

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