

SPATIO-TEMPORAL DISTRIBUTION OF ZOOPLANKTON BETWEEN MACROPHYTE AND OPEN WATER ZONES OF LAKE WĄSOWSKIE

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Summary. Spatial selectivity of zooplankton communities relating to different habitat preferences or temporal segregation relating to different patterns of seasonal distribution is a typical behaviour of both rotifers and crustaceans in freshwater ecosystems. This is why the main purpose of this study was to determine the seasonal (including spring, summer and autumn) distribution of zooplankton communities between two stands of macrophytes and, comparatively, the pelagic zone of Wąsowskie Lake, situated in a pastoral catchment area. Rotifers were most diverse in the summer. The number of crustacean species rose systematically from spring to autumn. Rotifers were found to dominate over Crustacea; this reflects the relations between planctonic organisms in the trophic pyramid in lakes with fish predation. Only one species – *Keratella cochlearis* – dominated in all the stations and in the three examined seasons. Rotifer densities decreased from spring to autumn, while crustacean densities were the highest in the summer and the lowest in spring. Also eight zooplankton species densities revealed significant differences between particular seasons. *Keratella quadrata*, *Notholca foliacea* and *Synchaeta pectinata* prevailed in the spring, *Colurella uncinata*, *Gastropus stylifer*, *Lepadella patella* and *Trichocerca similis* in the summer period, while *Ceriodaphnia quadrangula* dominated in the autumn. The mean Shannon-Weaver index values differed for both groups of zooplankton. The highest diversity index of the crustacean community was found among submerged vegetation in the summer months, which reflects the most stable conditions within the habitat created by spatially and morphologically complicated macrophytes.

Key words: rotifers, crustaceans, seasonal changes, species diversity, aquatic vegetation

INTRODUCTION

The distribution of zooplankton organisms in freshwater ecosystems is often swarm-like in character, both in the littoral and in the pelagic zone [Abraham 1998, Harding 2001]. Moreover, the type of ecological habitat, especially when created by various aquatic plant species, has an influence on zooplankton community structure [Lille and Budd 1992, Kuczyńska-Kippen 2007]. It is considered

that zooplankton, and especially rotifers, are particularly appropriate for habitat analysis because of their quality richness and because they are able to inhabit a variety of environments [Pejler 1994].

The physical-chemical parameters of water, such as nutrient concentrations or oxygen conditions which are often a consequence of human activity in the catchment area, may shape the abundance and richness of microinvertebrate communities [Castro *et al.* 2005].

Spatial or temporal segregation, relating to the occupation of different habitats or following different patterns of seasonal distribution, is a typical behaviour of animal plankton in freshwater environments [Makarewicz and Likens 1975]. The seasonality of zooplankton in the open water areas has already been well investigated [Herzig 1987] in contrast to the littoral zone where seasonal changes are still not very well known. Also food availability modified by seasonal factors – temperature as well as light – may have an impact on rotifer and crustacean variety in particular seasons [Castro *et al.* 2005].

The aim of the present study was to determine the seasonal (three successive seasons: spring, summer and autumn) distribution of zooplankton communities, both rotifers and crustaceans, between two stands of aquatic vegetation and, comparatively, the zone of open water of Wąsowskie Lake, situated within an agricultural catchment area. Moreover, it was planned to compare the structure of dominant species between stations and seasons.

STUDY AREA AND METHODS

The field studies were carried out during the spring, summer and autumn (from April to September) of 2001. The samples were taken on the 20th of every month at the same hour.

The examined lake is situated in the Wielkopolska region (52° 56,8'S; 17° 44,5'W) in the western part of Poland. This reservoir has an area of about 58 ha and a maximum depth of 25.3 m, but the mean depth is 12 m. The catchment area is mostly pastoral. The water quality of this lake was good – qualified in the second class of water cleanliness (Polish water quality classification). Moreover, the lavaret (*Coregonus lavaretus*) and european whitefish (*Coregonus albula*) were found in Wąsowskie lake and both of those fish species prefer clean water conditions [Konarska and Zielińska 1993].

The material was collected from three stations: two situated among stands of *Myriophyllum verticillatum* L. and *Elodea canadensis* L. (Rich.) and one in the open water zone. Samples of a total volume of 20 L were taken from the surface layer (0–1.0 m); they were concentrated using a 45-µm plankton net and were fixed immediately with 4% formalin.

Species diversity of rotifers and crustaceans inhabiting different habitats was examined using the Shannon-Weaver index which takes into consideration

also quantitative relations between species [Margalef 1957]. The U-Mann test was used for statistical analysis in order to evaluate the differences in the density of zooplankton between particular habitats and seasons (N = 18).

RESULTS

There were 65 zooplankton species identified in total (45 Rotifera, 20 Crustacea). Both groups of zooplankton revealed the highest mean species diversity in the zone of open water. The number of crustacean species rose systematically from spring to autumn, while rotifers were most diverse in the summer (Fig. 1).

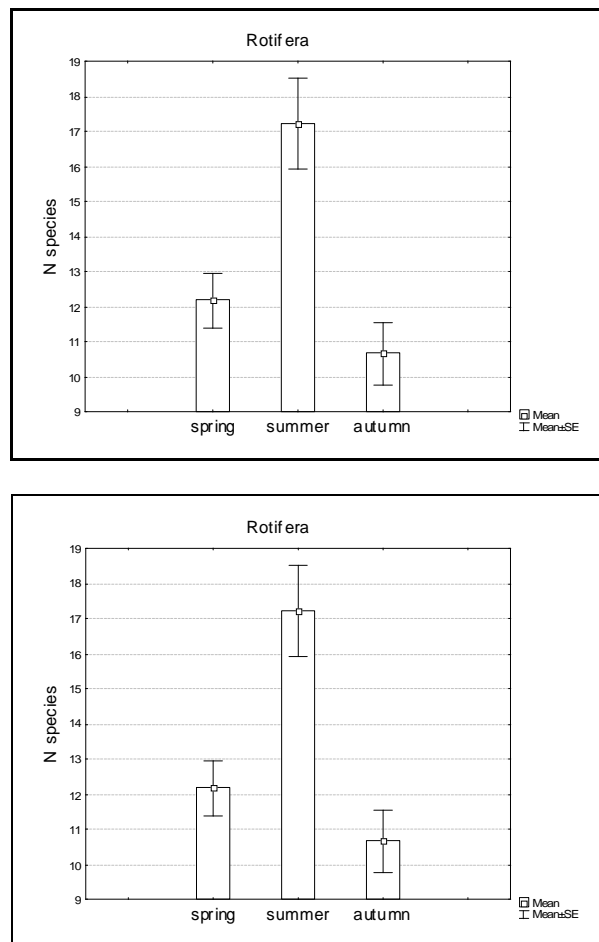


Fig. 1. Numbers of Rotifera and Crustacea species in different seasons
The Shannon-Weaver index value for Rotifera varied between 2.0 and 2.7,

with the highest species diversity found during the summer period (Tab. 1). The species diversity index for crustacean communities also differed, reaching values between 0.1 and 1.73. The highest diversity of Crustacea community was recorded for the station located among elodeides in the summer months.

Table 1. Values of Shannon-Weaver diversity index for Rotifera and Crustacea

Rotifera	Spring	Summer	Autumn
water	2.22	2.39	2.17
elodeids 1	2	2.18	2.4
elodeids 2	2.21	2.7	2.2
Crustacea	Spring	Summer	Autumn
water	0.1	1.28	1.05
elodeids 1	0.65	1.68	1.39
elodeids 2	0.54	1.73	1.55

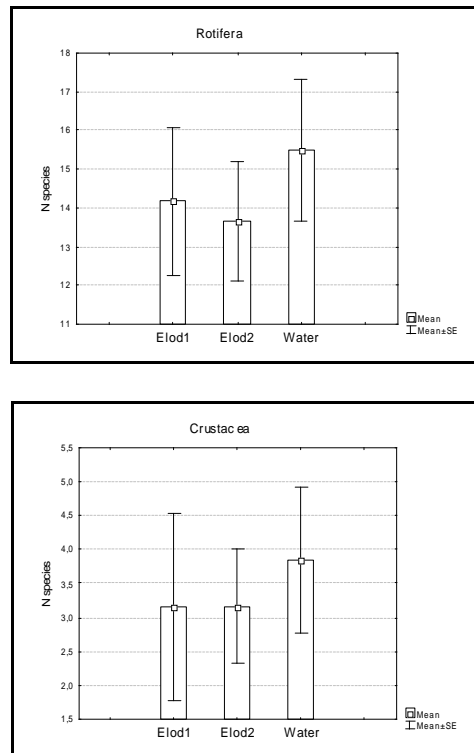


Fig. 2. Numbers of Rotifera and Crustacea species among different ecological habitats

Rotifera dominated over Crustacea in most cases, comprising between 32 and 100% of the total zooplankton densities of the investigated lake. No significant

ant differences ($p > 0.05$) were found considering the specific sampling stations (irrespective of the season), however, in the case of rotifers both zones located within macrophytes had higher densities compared to the open water station. At the same time crustaceans revealed an opposite distribution pattern with the highest abundance within the zone of open water (Fig. 2). The dominant community was created by 9 rotifer and 5 crustacean species. Only *Keratella cochlearis* (Gosse) dominated in all the stations and in the three examined seasons. This species dominated in nearly 90% of the samples. *Filinia terminalis* (Plate), *Synchaeta pectinata* Ehrenberg and *Daphnia cucullata* Sars dominated in the spring, while *Colurela uncinata* (O.F. Müller), *Pompholyx sulcata* (Hudson) and *Diaphanosoma brachyurum* (Lievin) dominated in the summer (Tab. 1). Most of the dominating species did not reveal a preference towards any habitat.

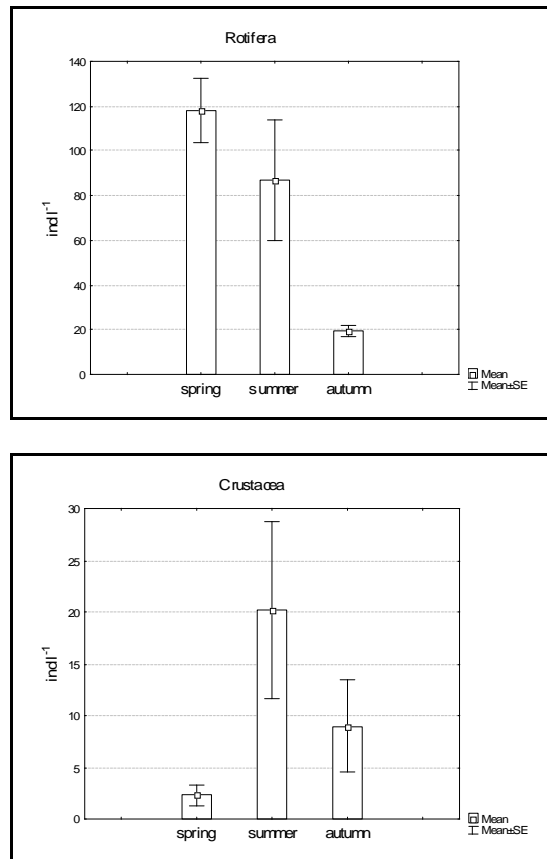


Fig. 3. Density of Rotifera and Crustacea in different seasons

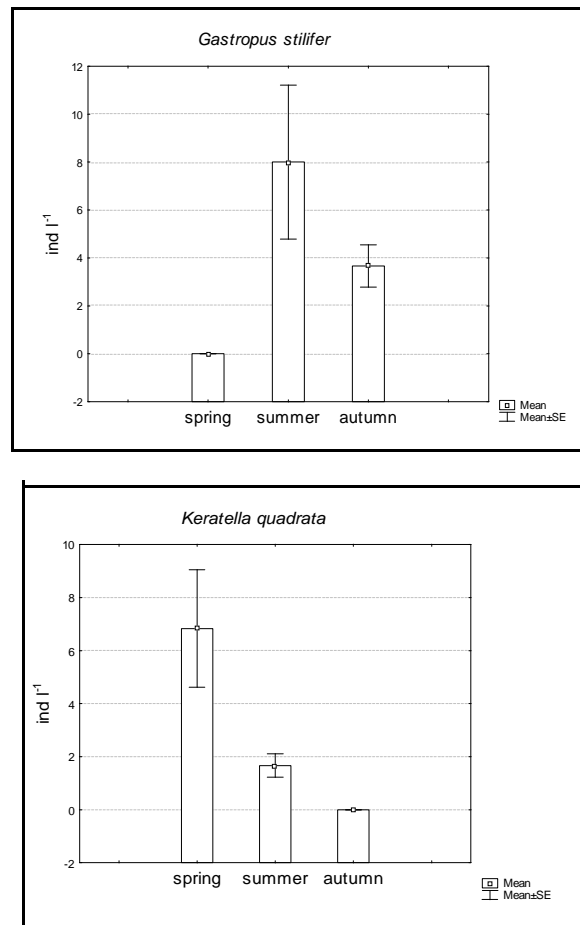


Fig. 4. Density of *Gastropus stylifer* and *Keratella quadrata* during different seasons

Analysing zooplankton seasonal changeability it was found that rotifers decreased from spring to autumn, while crustaceans reached significantly higher densities ($Z = -2.4749$, $p < 0.05$) in the summer and were much lower during the spring season (Fig. 3). Seasonal differentiation also concerned eight species. Species such as *Colurella uncinata* (O.F. Müller) ($Z = -2.1213$, $p < 0.05$), *Gastropus stylifer* Imhof ($Z = -3.1820$, $p < 0.01$), *Lepadella patella* (O.F. Müller) ($Z = -2.8284$, $p < 0.01$) and *Trichocerca similis* (Wierzejski) ($Z = -2.4748$, $p < 0.05$) occurred in highest abundance in the summer, while *Keratella quadrata* (O.F. Müller) ($Z = 2.3570$, $p < 0.05$), *Notholca foliacea* (Ehrenberg) ($Z = 2.0035$, $p < 0.05$) and *Synchaeta pectinata* Ehrenberg ($Z = 2.9463$, $p < 0.01$) in the spring (Fig. 4). *Ceriodaphnia quadrangula* (O.F. Müller) ($Z = -2.1214$, $p < 0.05$) reached their highest population in the autumn.

DISCUSSION

Rotifera were found to dominate over Crustacea in most of the samples. This distribution pattern of particular zooplankton groups is often typical for lake ecosystems and reflects the relations between planktonic organisms in the trophic pyramid. This can be a consequence of fish predators (present in the lake) which prefer consuming the larger groups of zooplankton – crustaceans [Lampert and Sommer 2001] and therefore rotifers build the most abundant community. In lakes there is not a single kind of predation present but usually a combination of different predators from among vertebrate species [Warfe and Barmuta 2004, Van de Meutter *et al.* 2005]. González [1998] found that *Chaoborus* as well as fish predators are able to cause an increase in rotifer community abundance and a decrease of cladoceran numbers simultaneously.

Competition between Crustacea and Rotifera may also have an influence on the domination structure of the zooplankton communities in freshwater ecosystems [Gilbert and MacIsaac 1989]. The structure of dominance reflects the interactions between particular organisms since it relates to both behavioural differences and fitness among individuals within a population [Krebs and Davies 1997]. It also influences particular species selectivity towards a specific habitat, the migratory behaviour of planktonic organisms or food availability, which may also differ between certain habitats within a single water body. The spatial analysis, including different habitats, of the dominating species of zooplankton communities did not reveal a preference towards any habitat, while the seasonal analysis of the dominating structure of zooplankters revealed that three species of pelagic character [Flössner 1972, Radwan *et al.* 2004] – *Filinia terminalis*, *Synchaeta pectinata* and *Daphnia cucullata* dominated in the spring, while three other species – *Colurella uncinata*, *Pompholyx sulcata* and *Diaphanosoma brachyurum* dominated in the summer. The only species which dominated at all the stations throughout the three successive seasons was *Keratella cochlearis*. This species, which is one of the most common representatives of the family Brachionidae and is known to inhabit a diverse range of waters [Pejler and Bērziņš 1989], is also believed to be the most common freshwater metazoan in the world [Koste 1978].

The analyses of zooplankton seasonal abundance distribution revealed two different patterns for the two groups of zooplankton communities. It was noticed that rotifer densities decreased from spring to autumn, while crustaceans reached significantly higher numbers in the summer period and the lowest during the spring season. Among single species significant differences were found in the case of eight species. *Keratella quadrata*, *Notholca foliacea* and *Synchaeta pectinata* prevailed in the spring. Those three species may often build abundant communities in waters of low temperatures [Radwan *et al.* 2004]. Other groups of species, such as *Colurella uncinata*, *Gastropus stylifer*, *Lepadella patella* and *Trichocerca similis*, all representatives of rotifers, occurred in the highest abundance

in the summer period, when the macrophyte species are at the optimum of their development and this is why in this group species of both pelagic and littoral origin prevailed. The preference of rotifer species towards the summer was also confirmed in the mean rotifer species number and the Shannon-Weaver index values which were the highest in this season. The life cycles of zooplankton organisms often relate positively to temperature, therefore most of the rotifer species reached their maximum abundance in the summer [Lampert and Sommer 2001]. Only one cladoceran – *Ceriodaphnia quadrangula* – revealed significantly higher densities in the autumn, while the mean Shannon-Weaver index values for this group of animals were highest also in the summer period. Moreover, the highest diversity of the crustacean community was found for the station situated among submerged vegetation. The littoral zone of lakes is often characterised by rich and very diverse zooplankton communities [Gliwicz and Rybak 1976, Havens 1991], which was proved in the case of lake Wąsowskie. Analysing various stations in a certain water body reveals that the most diverse communities are very often found among stands within elodeids which create a favourable anti-predation refuge against a number of predators, both invertebrate and vertebrates [Kuczyńska-Kippen and Nagengast 2006]. These ecological types of macrophytes also often serve as a nutritional source for their inhabiting organisms [Jones *et al.* 2000], providing them with algae available in the water filling the spaces between the plant stems as well as with periphyton which contains high amounts of detritus, carbonates and numerous bacteria accompanying the epiphytic algae [Gons 1979].

CONCLUSIONS

1. A seasonal analysis of zooplankton community structure of Lake Wąsowskie revealed a differentiated pattern of abundance and species diversity of particular taxonomic groups of animal plankton.

2. The highest densities of Rotifera were observed in the spring samples, contrary to the autumn period. Crustacea, however, reached the maximum abundance in the summer samples.

3. The species diversity measured according to the Shannon-Weaver index was highest in the summer period for rotifers and in the case of crustaceans during the autumn.

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PRZESTRZENNE I SEZONOWE ROZMIESZCZENIE UGRUPOWAŃ ZOOPLANKTONU POMIĘDZY MAKROFITAMI I OTWARTĄ TONIĄ WODNĄ JEZIORA WĄSOWSKIEGO

Streszczenie. Rozmieszczenie przestrzenne zbiorowisk zooplanktonu związane z wybiórczością siedliskową czy też czasową segregacją organizmów związaną z sezonowością występowania poszczególnych gatunków należą do typowych zachowań planktonu zwierzęcego. Dlatego głównym celem pracy była wskazanie sezonowych (wiosna, lato i jesień) zmian rozmieszczenia ugrupowań zooplanktonu pomiędzy dwoma stanowiskami zlokalizowanymi w obrębie makrofitów oraz porównawczo w toni Jeziora Wąsowskiego, położonego w zlewni rolniczej. Różnorodność ugrupowań wrotków była największa w okresie letnim, podczas gdy skorupiaków rosła od wiosny do jesieni. Wrotki dominowały nad skorupiakami, co jest typowe dla jezior z siną presją ryb. Wyłącznie jeden gatunek – *Keratella cochlearis* – dominował na wszystkich badanych stanowiskach w każdej z analizowanych pór roku. Liczebności wrotków zmniejszały się od wiosny do jesieni, podczas gdy skorupiaki osiągnęły najwyższe liczebności w okresie letnim, a najniższe wiosną. Ponadto osiem gatunków zooplanktonu charakteryzowało się zróżnicowaniem sezonowym rozmieszczenia ich liczebności. *K. quadrata*, *Notholca foliacea* i *Synchaeta pectinata* przeważały wiosną, *Colurella unicata*, *Gastropus stylifer*, *Lepadella patella* i *Trichocerca similis* latem, podczas gdy *Ceriodaphnia quadrangula* w okresie jesiennym. Wartość wskaźnika różnorodności gatunkowej różniła się dla obu grup zooplanktonu. Największą wartość tego wskaźnika odnotowano w przypadku skorupiaków w obrębie elodeidów w okresie letnim, co wskazuje na najbardziej stabilne warunki w siedlisku tworzonym przez makrofity o dużym stopniu komplikacji przestrzennej i morfologicznej.

Słowa kluczowe: wrotki, skorupiaki, sezonowe zmiany, różnorodność gatunkowa, roślinność wodna