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The diurnal distribution of cladocerans in a bed of *Myriophyllum verticillatum* in Lake Wielkowiejskie

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Abstract

The main aim of the study was to analyze diurnal changes in the composition and dynamics of the cladoceran community among three stations located along a horizontal transect that included the central part of a *Myriophyllum verticillatum* bed at the perimeter of a macrophyte stand and the open water zone of neighboring vegetated stations.

Typically littoral species distinctly dominated the material examined. *Ceriodaphnia quadrangula* significantly influenced the total crustacean community.

The maximum abundance of littoral species was noted in the middle part of the plant stand while the minimum was in the open water. These species revealed a similar pattern of diurnal distribution, irrespective of the station, with the highest numbers at night and the lowest during the day and morning. A similar pattern of diurnal distribution was also observed for pelagic species that exhibited significant differences in the open water zone between the day (the lowest numbers) and night (the highest) samplings.

It was suggested that the diurnal distribution of cladoceran representatives between the macrophyte bed and the open water zone of Lake Wielkowiejskie might have been influenced by young fish predation (pelagic species) and by typical adaptations of particular species to living within the heterogeneous habitat of a macrophyte stand (littoral species).

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INTRODUCTION

Freshwater planktonic communities are comprised of a wide diversity of organisms which are an essential part of lake food webs. The cladoceran group (Cladocera) plays a very important role in the functioning of zooplankton communities. Their physiological and morphological abilities allow them to react rapidly to numerous changes in environmental conditions. The structure of the zooplankton in a lake depends on a multiplicity of environmental factors, including the presence of invertebrate and vertebrate predators. Crustaceans of shallow and macrophyte-dominated lakes often use aquatic vegetation as concealment from predators, and the various spatial and morphological structures of macrophytes provide the organisms inhabiting them with a range of protective conditions within the architecturally complicated conglomeration of aquatic plants (Diehl 1992). The more structurally complex plants are, the greater are the protective conditions such habitats provide (Warfe and Barmuta 2004).

Furthermore, physical and chemical factors, including water temperature, oxygen concentration, as well as concentrations of nutrients, which are related to the availability of nutritional sources, can influence the crustacean community structure (Lampert and Sommer 1999). In freshwater ecosystems phytoplankton serve as an important source of food. However, animals that inhabit the littoral zone permanently or use it temporarily must look for an alternative nutritional base. It has been demonstrated that macrophytes may also provide zooplankton with a source of food (Jones et al. 2000, Degans and De Meester 2002), which apart from algae consists of a variety of protozoans, bacteria, and detritus.

The composition and dynamics of a cladoceran community may vary among different stations and in successive hours of the diel cycle. Many freshwater animals, including cladoceran species, exhibit an ability to undertake active migrations, and cladoceran species are among them (Hays 2003). An example of such behavior is the vertical migrations which are usually observed in deep stratified lakes. The organisms move cyclically in the water column, from the surface waters in the direction of the deeper and colder waters and back again (Horppila, 1997). However, in shallow lakes the opportunity for crustaceans to move along a vertical profile is restricted due to the lack of a deep aphotic layers, which provide concealment. In this case zooplankton usually undertake horizontal migrations. These are typical for shallow lakes with large macrophyte-covered areas (Lampert 1993). In such reservoirs different species of aquatic plants create various microhabitats, which are used as a refuge for pelagic species that seek out safe places to hide from predatory fish during daylight hours (Kuczyńska-Kippen and Nagengast 2006). Moreover,

different parts of the same macrophyte stand may provide concealment for zooplankters (Kuczyńska-Kippen 2001, 2003); however, it can be expected that the effectiveness of particular microhabitats is variable.

The aim of the present investigation was to determine the diurnal changes in the composition and dynamics of the cladoceran community among three stations located along a horizontal transect that included the central part of a *Myriophyllum verticillatum* bed at the perimeter of a macrophyte stand and the open water zone of neighboring vegetated stations.

MATERIALS AND METHODS

This study was based on biological research conducted on Lake Wielkowiejskie, which is located in the northwestern part of Wielkopolski National Park near the town of Stęszew. The area of the lake is 13.3 ha, and it has a maximum depth of 2.8 m (1.4 m mean depth).

Lake Wielkowiejskie is a typical shallow macrophyte-dominated lake with a belt of rushes dominated by two species: *Typha angustifolia* L. and *Phragmites australis* (Cav.) Steud. Nearly the entire basin of the lake is covered by submerged macrophytes (*Chara tomentosa* L., *C. hispida* L., *Myriophyllum verticillatum* L., *Nitellopsis obtusa* (Desvaux) Groves, *Utricularia vulgaris* L.). Moreover, representatives of floating-leaf vegetation, stands of *Nymphaea alba* L., cover approximately 20% of the water surface. The macrophyte beds in the lake examined were single-species stands separated from each other (Kuczyńska-Kippen and Nagengast 2006). Lake Wielkowiejskie is characterized by a fully-developed hydromacrophyte zonal system.

The zooplankton material was collected on July 17-18, 2004 in a horizontal transect (Fig. 1). Samples of a volume of 5 l each were taken in triplicate at each

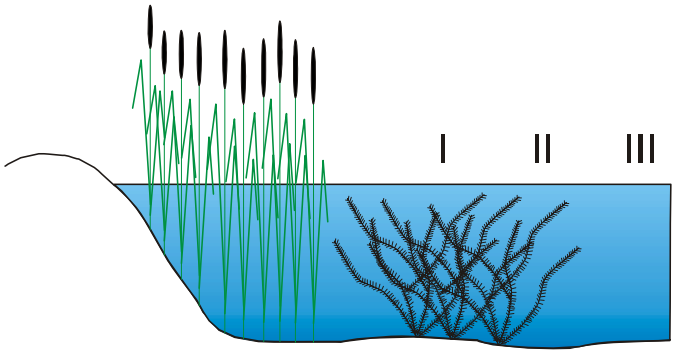

Fig. 1. Zooplankton community sampling stations in Lake Wielkowiejskie (station I - *Myriophyllum* bed; II - perimiter; III - open water zone).

site using a plexiglass core sampler. Then they were concentrated using a 45-µm plankton net and fixed with 4% formalin. The zooplankton samples were sedimented in the laboratory and dyed using Bengal Rose for later identification. Zooplankton was sampled four times within a 24 hour cycle, including in the morning and day and at dusk and night.

Non-parametric analysis of variance (Kruskal-Wallis) was used to identify the differences in the zooplankton densities between particular stations and seasons during the diel examination (N=36).

The relationship between particular macrophytes (stem length and dry mass) and physical-chemical parameters and cladoceran densities was measured using Pearson's adjusted R2 Correlation Coefficient.

RESULTS

The analysis of the cladoceran community among particular stations of Lake Wielkowiejskie indicated the distinct domination of typically littoral species, among which *Ceriodaphnia quadrangula* (O.F. Müller), *Alonella exigua* (Lilljeborg), and *Camptocercus rectirostris* (Schoedler) were most abundant. It was found that of the total of 26 identified species, 24 belonged to plant-associated forms.

The emohatic dominant was *C. quadrangula*, which had the greatest influence on the total cladoceran numbers. The total densities of this species reached 61% of the total abundance of the examined group of animals.

There were significant differences in the density distribution of *C. quadrangula* among the three investigated stations. The maximum abundance of this species was found in the middle part of the *Myriophyllum verticillatum* bed, irrespective of sampling time. During the day ($H_{2.9} = 7.2605$; $p = 0.027$) and at dusk ($H_{2.9} = 6.4889$; $p = 0.039$), the analyses indicated that there were significant differences among the results obtained for *C. quadrangula* between the open water zone station and the central part of the vegetated stand. The lowest numbers of this cladoceran were recorded in the open water zone, while the highest were inside the *Myriophyllum* bed (Fig. 2). No significant differences were found among sampling stations for any of the pelagic species.

Furthermore, upon examining the distribution of *C. quadrangula* abundance, significant differences were also obtained, in particular, among the four sampling hours (day, dusk, night and morning). It was noted that in the central part of the studied macrophyte bed the cladoceran numbers at the night sampling were significantly higher than those from the morning sampling ($H_{3.12} = 9.4304$; $p = 0.024$). Moreover, *C. quadrangula* as well as the pelagic species *Diaphanosoma brachyurum* (Lievin) ($H_{3.12} = 8.0803$; $p = 0.044$)

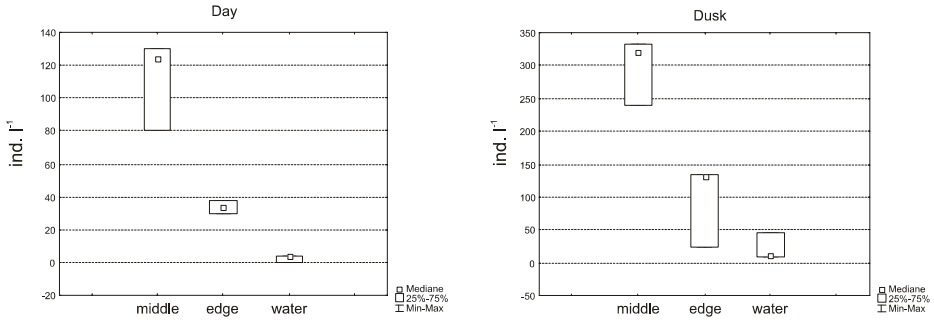

Fig. 2. Density of distribution of *Ceriodaphnia quadrangula* between particular sampling stations during the day and at dusk.

exhibited the highest densities during night sampling in comparison to the lowest densities during the day-light hours in the area of open water ($H_{3.12}$ = 10.0446; p = 0.018; Fig. 3).

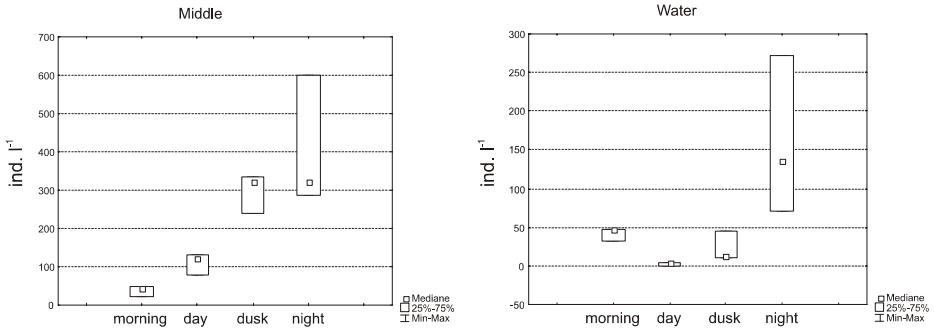

Fig. 3. Density distribution of *Ceriodaphnia quadrangula* between individual and particular sampling seasons in the middle part of the *Myriophyllum verticillatum* stand and in the open water area.

A total of six correlations between cladoceran densities and environmental factors were observed. Zooplankton positively correlated with chlorophyll *a* (total cladoceran abundance and *Diaphanosoma brachyurum* densities), nitrites (*D. brachyurum* densities), and total reactive phosphorus (total cladoceran abundance, *Ceriodaphnia quadrangula* and *Alonella exigua* densities) (Table 1).

Table 1

Correlation ratios between the densities of particular cladoceran species and chemical parameters (nitrites – NO_2, total reactive phosphorus – TRP) and chlorophyll *a* concentration (chl *a*)

species	parameter	r	p
total Cladocera	chl *a*	0.71	0.010
	TRP	0.74	0.006
Ceriodaphnia quadrangula (O. F. Müller)	TRP	0.76	0.005
	chl *a*	0.74	0.006
	NO_2	0.61	0.036
	TRP	0.85	0.001

DISCUSSION

The results of the diurnal study carried out on the shallow Lake Wielkowiejskie indicate that typically littoral forms of the Cladocera community dominate. This majority of littoral forms in the taxonomical structure of cladocerans from the water body examined was the consequence of two forms. Firstly, the investigation was conducted along a transect that crossed the central and perimeter areas of a macrophyte bed and finished in the water area neighboring the vegetated stand. This is why littoral species prevailed. It known that heterogenic habitats, like aquatic plant stands, offer more potential niches for the organisms that inhabit them. With the increase of the morphological and spatial complication of a macrophyte habitat, the creation of available niches also increases (Pianka 1988, Krebs 2001). Furthermore, the littoral zone of Lake Wielkowiejskie, created by various ecological types of aquatic plans, covers the majority of the lake bottom, which favors the great taxonomical variation of macrophyte-associated species. Thus, there were only two typically limnetic species found, which usually find optimum conditions in the open water zone; however, they often migrate into the littoral zone at certain times during the 24-hour cycle or are often washed into vegetated stands by wave action.

The maximum abundance of littoral species was noted in the middle part of the plant stand, while small densities of them were noted in the open water zone neighboring the macrophyte stand. Such a significant pattern of abundance distribution was recorded in the case of *Ceriodaphnia quadrangula.* This species prefers small and shallow lakes with large macrophyte-covered areas, such as Lake Wielkowiejskie. This cladoceran species is often found in warm waters. *Ceriodaphnia quadrangula* was the strongest dominant among the

cladoceran community as it had optimum conditions within the littoral zone of the examined lake. Moreover, another two species, *Alonella exigua* and *Camptocercus rectirostris*, both exhibited similar diurnal and spatial distribution among the studied stations; however, their abundance was much lower and was not significant. *Alonella exigua* prefers particular water plants, mainly *Myriophyllum* sp. and *Ceratophyllum* sp., while a second species from this genus, *A. excisa,* has optimum conditions among *Chara* habitats (Flössner 1972). This has also been confirmed in the case of Lake Wielkowiejskie (Kuczyńska-Kippen 2006).

A different pattern of diurnal distribution among the analyzed stations was recorded for pelagic species such as *Bosmina longirostris* and *Diaphanosoma brachyurum*, both of which were at minimum abundance in the open water zone during the day. The maximum density of *D. brachyurum* in open waters was noted in the night samples. This type of diel spatial distribution pattern in this cladoceran species is typical for pelagic zooplankters that seek refuge in the vegetated areas of shallow lakes and migrate into open waters during the dark hours. Aquatic plants can offer pelagic species effective refuge (Lauridsen and Buenk 1996), the effectiveness of which may depend on different macrophyte species due to varying growth forms or densities (Stansfield et al. 1997). One of the most important factors that often shapes the Cladocera and other zooplanktonic invertebrate communities is vertebrate predatory pressure. Since these predators use sight to hunt for prey, zooplankton undertake horizontal movements (mostly pelagic species) or use macrophytes as anti-predator refuge during the day in lakes where planktivorous fish are present (Timms and Moss 1984, Moss et al. 1998). Moreover, a number of other envinomental factors, such as the availability of food sources or physical-chemical features, which often vary between particular sampling hours within closely situated sampling stations (Kuczyńska-Kippen 2006), may also affect the diurnal distribution of particular groups or species in zooplankton communities.

Furthermore, pelagic cladocerans were noted more frequently at the perimeter of *Myriophyllum verticillatum* stands (Basińska 2005). A similar effect, where pelagic species remained at higher densities in the transitional zone of a macrophyte bed was observed by Schriver et al. (1995), Kairesalo et al. (1998), and Kuczyńska-Kippen (2003, 2006).

Among the environmental factors analyzed, zooplankton densities correlated most strongly with chlorophyll *a* and with total reactive phosphorus. A positive relationship often exists between the algae primary production expressed as chlorophyll *a* concentration and some freshwater organisms. Dejen et al. (2004), in their examination of the temporal and spatial distribution of microcrustaceans in a tropical lake, also found a positive correlation between the abundance of *Diaphanosoma* and the concentration of chlorophyll *a*. With

reference to phosphorus concentration, in their examination of the influence habitat characteristics have on the structure of the rotifer and cladoceran communities, Kuczyńska-Kippen and Nagengast (2006) found that it had a positive impact on the density of most invertebrate taxa. So, too, did Cyr and Downing (1988), who examined 10 lakes in Québec (Canada).

The analysis of cladoceran diel distribution within the *Myriophyllum verticillatum* stand and the surrounding open water zone of Lake Wielkowiejskie revealed that young fish predation influenced mainly pelagic species. However, the typical adaptations of particular species to living in the pelagic zone or within a heterogeneous habitat (macrophyte stand) also played a role in the diurnal distribution pattern of cladoceran densities.

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