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The diurnal distribution of the zooplankton community of the littoral zone of Lake Wielkowiejskie (Wielkopolski National Park, Poland)

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Abstract

The main aim of this study was to analyze the diel distribution of zooplankton communities within the zones of *Nymphaea albae, Myriophyllum verticillatum,* and *Typha angustifolia*, and, compared to that, in the open water area of a lake. It also aimed to analyze the relationship between zooplankton densities and the concentration of physicochemical factors and chlorophyll *a* content.

A total of 149 zooplankton taxa were noted, and, despite the narrow range of the research in the analyzed lake, some rare species were noted, among which two - *Colurella sinistra* and *Lecane inopinata* – were recorded for the first time among Polish fauna. The rush zone was taxonomically the richest, while the open water area was the poorest. The highest number of

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individuals was observed in the *Myriophyllum* bed, while the lowest was noted in the zone dominated by *Nymphaea alba*.

The highest densities of zooplankton occurred at dusk, while the lowest occurred during the day, irrespective of the sampling station. Because Lake Wielkowiejskie is a shallow and macrophyte-dominated water body, the differences in the diurnal distribution of zooplankton communities may suggest horizontal migrations between the pelagic zone and the phytolittoral, as well as between particular macrophyte stands.

A positive correlation between the densities of some zooplankters and the concentration of chlorophyll *a* was found, while a negative relationship with the concentration of nitrites was recorded for *Lecane quadridentata* and *Alonella nana*.

INTRODUCTION

Particular zones within a water body create differentiated environmental conditions, where specific groups of organisms may be found. In particular, the macrophyte-dominated area within lakes favors a quality and quantity richness of both plant and animal organisms. The littoral communities of zooplankton consist of the same species as the pelagic zone possesses; however, typical littoral forms prevail as a multiciplicity of rotifers and crustaceans are, in evolutionary terms, littoral forms (Pejler 1995). Only some species have managed to adapt to living within the open water; hence both groups are classified as pelagic or littoral forms (Wetzel 1975).

The character of the spatial distribution of zooplankton assemblages is affected by many abiotic and biotic factors, such as temperature, light, oxygen, as well as food, chemical changeability, invertebrate and fish predation, and the available food conditions (Leibold 1991). Moreover, the effect of competition among particular zooplankton groups or species, and competition between zooplankton and other freshwater organisms, cannot be ignored (Wickham and Gilbert 1990). Different macrophyte species are characterized by differences of morphology and of the spatial structure of their stems. It has been found that the density and biomass of the plant habitat corresponded positively with zooplankton abundance. The most complicated architecture of vegetated habitat is considered to be the most profitable, in terms of offering concealment spaces for both rotifers and crustaceans (Kuczyńska-Kippen and Nagengast 2006).

Another important factor in the structuring of plankton assemblages is food composition and its concentration in the lake water (Bogdan and Gilbert 1987).

Rotifer and especially crustacean spatial distribution between particular zones of a lake are also modified by the process of diel migrations. It is also known that abiotic factors vary within the littoral zone of lakes, and that these may change in the diurnal cycle (Burks et al. 2002), and, thus, affect the freshwater organisms. Migrations of zooplankton have already been the focus of research (Gliwicz 1986); however, most studies have concentrated on diel vertical migrations. Less information is available on the horizontal migrations in

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macrophyte-dominated lakes, where the opportunity for vertical migrations is restricted because of the shallowness of the water column. In such lakes, zooplankton migrate diurnally between the littoral zone, often created by differentiated macrophyte habitats, and the open water area. This migration was the subject of research conducted on Lake Wielkowiejskie.

The hypothesis was advanced that the distribution of zooplankton communities within particular zones of a lake (*Nymphaea albae, Myriophyllum verticillatum, Typha angustifolia*, and, in comparison to this, in the open water area between macrophyte stands) in the diel cycle can be attributed to changes in biotic and abiotic factors, which also change between particular periods in the 24-hour cycle.

MATERIALS AND METHODS

Lake Wielkowiejskie is a macrophyte-dominated lake situated in Wielkopolski National Park, with an area of 13.3 ha, a maximum depth of 2.8 m, and a mean depth of 1.4 m. Research on the diurnal spatial distribution of zooplankton in the various stands of water vegetation (including three macrophyte species – *Typha angustifolia*, *Myriophyllum verticillatum*, and *Nymphaea alba*), and, in comparison, in the open water zone situated between the macrophyte stands, was carried out in August 2004. The sampling stations were located along a transect of about 30 m in length. Sampling was carried out four times within the 24-hour cycle. Zooplankton samples were taken in triplicate, using a 5-l sampler from randomly chosen places within the vegetated stand, concentrated using a 45-µm plankton net, and fixed with 4% formalin.

Chemical analysis was made, according to Standard Methods for the Examination of Water and Wastewater (1992), in order to evaluate the content of N and P of the water filling the spaces between the plant stems. Chlorophyll *a* concentration (corrected for pheopigments) was determined fluorometrically.

The Mann-Whitney U-test was used in order to determine the effect of site and time on the distribution of the zooplankton community (N=48). The relationship between habitat variables and the numbers of zooplankton communities was verified with the Pearson correlation.

RESULTS

The presence of 149 zooplankton taxa (95 Rotifera, 36 Cladocera, 18 Copepoda) was found, and, despite the narrow range of the research in the analyzed lake, some rare species were noted, among which two - *Colurella sinistra* Carlin and *Lecane inopinata* Harring and Myers – were recorded for the first time among Polish fauna.

The rush zone possessed the highest number of identified species (132), which was mainly due to the taxonomical abundance of crustaceans in this habitat (35 Cladocera, 17 Copepoda). In contrast, the station located within the open water area was characterized by the poorest taxonomical structure (49 Rotifera, 15 Cladocera, 8 Copepoda). The zones of nymphaeids and elodeids contained, respectively, 116 species (73 Rotifera, 28 Cladocera, 15 Copepoda), and 126 species (81 Rotifera, 30 Cladocera, 15 Copepoda).

The zone dominated by the whorled water-milfoil (*Myriophyllum verticillatum*) was characterized by the highest total abundance of zooplankton communities (1797 ind. l^{-1}), with the maximum values obtained by rotifers (1242 ind. l^{-1}) and copepods (163 ind. l^{-1}). However, cladocerans reached their highest densities within the stand of narrow-leaved cattail (*Typha angustifolia*) (443 ind. l^{-1}), where the total number of individuals was 1238 ind. l^{-1}.

A high total of zooplankton densities was noted in the open water area (1296 ind. l^{-1}), compared to the remaining stations, as a result of high densities (1049 ind. l^{-1}) of a few rotifer species described as typically limnetic forms, such as *Keratella cochlearis* Gosse, *Polyarthra vulgaris* Carlin, *Trichocerca similis* (Wierzejski) (among rotifers), and *Bosmina longirostris* (O.F. Müller) (among crustaceans). In contrast, the lowest zooplankton abundance was recorded in nymphaeids (582 ind. l^{-1}) (Fig. 1).

The analysis of the diurnal distribution of the rotifer and crustacean community demonstrated that the highest abundance of zooplankton specimens occurred at dusk, while the lowest occurred during the day, irrespective of the sampling station (Fig. 2).

The highest concentrations of $N\text{-}NO_2$ (0.002 mg l^{-1}) were found in six samples (N=16), while in three samples it was not detected at all. The highest concentration of chlorophyll *a* was found in the stand of *Myriophyllum* at dusk (29.9 μg l^{-1}), while the lowest appeared in the open water zone also at dusk (3 μg l^{-1}).

Additionally, a positive correlation between the densities of some zooplankton organisms (Bdelloidea -r=0.52, $p<0.05$; *Colurella uncinata* (O.F. Müller) -r=0.58, $p<0.05$; *Lepadella patella* (O.F. Müller) -r=0.56, $p<0.05$; *L. triptera* Ehrenberg -r=0.58, $p<0.05$; *Proales* sp. -r=0.51, $p<0.05$ and Harpacticoidae -r=0.61, $p<0.05$) and the concentration of chlorophyll *a* was found, while a negative relationship with the concentration of nitrites was recorded for *Lecane quadridentata* (Stenroos) -r=-0.53, $p<0.05$ and *Alonella nana* (Baird) -r=-0.52, $p<0.05$.

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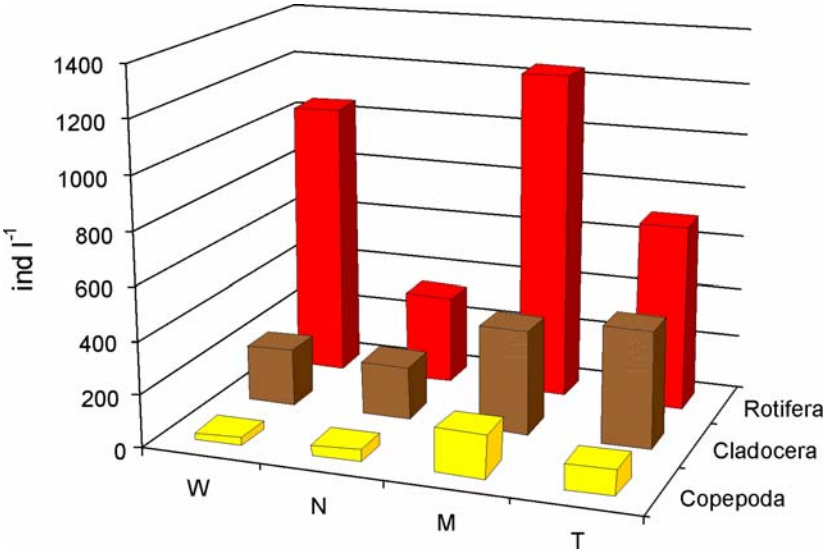


Fig. 1. Number of zooplankton individuals at particular stations of Lake Wielkowiejskie (W – open water zone, N – *Nymphaea alba*, M – *Myriophyllum verticillatum*, T – *Typha angustifolia*).

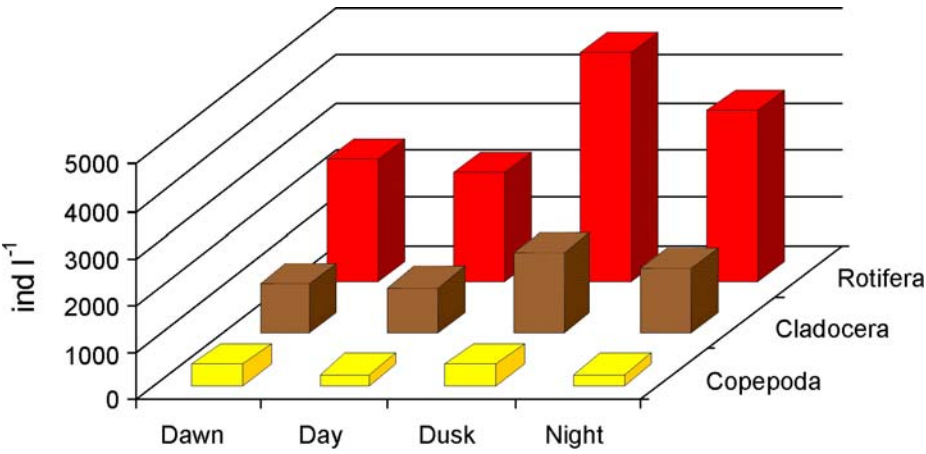


Fig. 2. Number of zooplankton individuals in particular sampling periods in Lake Wielkowiejskie.

DISCUSSION

The analysis of zooplankton from the various phytocoenosis of helophytes, elodeids, nymphaeids, and the open water zone of Lake Wielkowiejskie, revealed a differentiation in relation to the taxonomical structure and dynamics of the animal communities. Out of 149 zooplankton species, two - *Colurella sinistra* and *Lecane inopinata* – were found for the first time among Polish fauna (Radwan et al. 2004).

The zone dominated by *Typha angustifolia* was characterized by the most diverse zooplankton communities, which was mainly attributable to the taxonomical abundance of crustaceans in this area. At the same time, the open water zone, which is the most homogenic habitat, was the poorest. This relates to the fact that the more heterogenic physically and biologically complicated habitats are, the more available niches are created for inhabiting organisms (Gliwicz and Rybak 1976, Currie 1991). Thus the greatest richness of organisms will be found among more architecturally complex macrophyte stands.

Furthermore, the differentiation in the zooplankton community structure concerned the total densities between particular sampling stations. The highest abundance was found to be in the zone of the whorled leaf water-milfoil (*Myriophyllum verticillatum*), where the maximum numbers of individuals were recorded for rotifers and copepods. However, cladocerans reached their highest abundance in the bed of narrowleaf cattail (*Typha angustifolia*). Such a differentiation in the spatial distribution of particular groups of the zooplankton community may be related to the interactions between rotifers and crustaceans, as both groups of animal plankton often remain in strong competitive interaction (Wickham and Gilbert 1990), either through mechanical interference (Gilbert 1988), or exploitative competition (Fussmann 1996). Moreover, very high zooplankton densities were noted in the open water area, where typically pelagic species such as *Keratella cochlearis*, *Polyarthra vulgaris*, *Trichocerca similis*, and *Bosmina longirostris* prevailed. Their mass occurrence in the open water zone may also be related to 'shore avoidance' as described by, e.g., Saunders-Davies (1989), who found that densities of *Keratella cochlearis* and *Polyarthra vulgaris* increase with distance from the lake shore.

Contrary to both the zones above, the lowest numbers of zooplankton were found in the zone of nymphaeids, which, within the littoral zone, is one of the less morphologically and spatially complicated habitats (Kuczyńska-Kippen and Nagengast 2006). Similar results were obtained by Meerhoff et al. (2003) who, examining a macrophyte-dominated lake in Uruguay, found that the nymphaeids were characterized by the lowest zooplankton densities compared to other macrophyte stations.

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The differentiation in the species composition, and the total densities of zooplankton assemblages, between vegetated and non-vegetated zones, is probably connected with the higher complexity of the habitats within the littoral region of a lake, and also with the variation of morphological adaptations required for life in both of these habitats (Ruttner-Kolisko 1974). The increased structural complexity of the vegetated region reduces the predatory effect of fish (Crowder and Cooper 1982) by providing the inhabiting organisms with a variety of potential refuges. It can also increase periphyton biomass through expanding the substrate surface available for colonization; thus the potential nutritional source will vary among different macrophyte hosts (Blindow 1987), which may also influence the composition of zooplankton, which can feed directly on the periphyton.

The diurnal distribution of the rotifer and crustacean community revealed discrepancies in the following sampling seasons, irrespective of the station, which was most likely caused by horizontal migrations undertaken by some zooplankton species. It is possible that they may have migrated towards the dense *Utricularia vulgaris* stand, which was in close proximity to the sampling stations, or towards the *Chara* spp. zone that occupies great parts of the bottom of the Lake Wielkowiejskie. One of the reasons for zooplankton migration is avoidance of predators that use visual orientation in identifying their potential prey – planktivorous fish, as well as invertebrate predators such as insect larvae, *Hydra* sp. or Mysidae (Bohman et al. 2000). The effectiveness of refuge within a plant habitat relies on the great heterogeneity of the complex conglomeration of macrophytes. Furthermore, food availability may also influence the spatial distribution of zooplankton communities. In the littoral zone, apart from phytoplankton present in the interstem spaces, the nutritional source consists of periphytic algae, enriched by bacteria, protozoans and a large mass of detritus (Van Dijk 1993). Macrophytes, which differ in their architecture, in the fineness of leaves and also in the texture of the plant surface, influence the structure of epiphytic communities (Blindow 1987); hence zooplankton community structure may vary between particular plant species.

The analysis of the relationship between the zooplankton densities and physical-chemical features revealed a positive correlation for Bdelloidea, *Colurella uncinata*, *Lepadella triptera*, *Lepadella patella*, *Proales* sp., and Harpacticoidae, in the case of the concentration of chlorophyll *a*, which indicates the concentration of phytoplanktonic producers constituting a great part of the zooplankton food source.

The differences in the diurnal distribution of zooplankton communities in Lake Wielkowiejskie, which is a typical macrophyte-dominated water body, may suggest that horizontal migrations of plankton organisms between the open

water area and phytolittoral take place, as well as those between particular macrophyte stands.

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