ABSTRACT: Studies were conducted in littoral sand deposits of a eutrophic, deep lake (Lake Mikołajskie, Masurian Lakeland, Poland) in aim to test the hypothesis that epiphysoarenal (the most upper layer of sand deposits) may play a role of a refuge from visual predators for rotifers from adjacent water layer. However, a comparison of the daily vertical distribution of the rotifer community structure and densities in microlayers of the lake psammolittoral, i.e. adjacent water layer (5.0–0.0 cm), epiphysoarenal (0–0.5 cm) and three microlayers of endophysoarenal (0.5–1.0 cm, 1.0–1.5 cm and 1.5–2.0 cm) revealed a lack of up-and-down vertical migrations of the animals. During day and night hours, both on 5/6 and 11/12 July, rotifers were concentrated in epiphysoarenal. In all cases 64 to 85% of rotifer community inhabited this layer, whereas up to 4% occurred in adjacent water layer. Large and permanently renewed food resources (algae and bacteria) in the most upper layer of sand deposits form a very thin layer that can be called “a canteen”. This may explain permanent concentration of rotifers in the layer.

KEY WORDS: Rotifera, hydroarenal, psammomon, vertical distribution

Psammolittoral (sand sediments in lake shore zone) organisms inhabit very unstable environment depending, among others, on wave action, temperature (Ejsmont-Karabin 2005), morphometry of sand grains (Ejsmont-Karabin 2004, 2006) and concentration of oxygen and organic matter (Schmid-Araya 1998). Although vertical distribution of psammomon rotifers in hydroarenal (permanently submerged sands in lake littoral) is disturbed by wave action, some authors showed that the organisms are concentrated in the top 1 cm (Pennak 1940, Neel 1948, Ruttner-Kolisko 1953, 1954, Bielańska-Grajner 2001, 2004; Ejsmont-Karabin 2008). On the other hand, Pejler (1995) and Wallace and Ricci (2002) suggest that endopsammomon rotifers (i.e. rotifers inhabiting interstitial waters among sand grains) migrate into epibenthic (on a surface of bottom sediments) and epiphytic (on surfaces of macrophytes) habitats and occasionally even to planktonic ones. Reasons of these migrations are not known. Passive transport would be suggested as one of the most important between them, however, rotifers are resilient to this kind of disturbances (Wallace and Ricci 2002). Seasonal studies of microlayers in hydroarenal of Mikołajskie Lake (Ejsmont-Karabin 2008) revealed that rotifers are concentrated in a thin, 0.5 cm deep layer called epiphy-
This suggests that epihydroarenal may play a role of a refuge from predators like fish larvae for rotifers from adjacent water layers. If so, some differences between rotifer distribution in epi- (0−0.5 cm) and endohydroarenal (0.5−2.0 cm) during the day and night may be expected. The aim of the study was to test this hypothesis through a comparison of the daily vertical distribution of the rotifer community structure and densities in adjacent water layer (AWL), epihydroarenal (EPIH) and three successive microlayers of endohydroarenal (ENDOH).

Day and night studies were conducted on 5/6 July and 11/12 July 2007. Samples were taken in three replicates from a small, sandy and surrounded with reed stands bay of Lake Mikolajskie (area – 497.7 ha, maximal depth – 25.9 m, length of shoreline – 15100 m), 1.5 m from water’s line. Sampling cores taken with a 7.3 cm diameter plastic tube were divided into 5 fractions: 5.0–0 cm layer of water over sand (AWL) and sand layers: 0−0.5 cm (EPIH), 0.5−1.0 cm, 1.0−1.5 cm, 1.5−2.0 cm (ENDOH). The samples were shaken six times with 0.5 l of tap water and the supernatant was filtered through a 30 μm mesh-size net and fixed with 4% formalin. Each sample (=fraction) was elaborated as a whole and all rotifer species were determined and counted.

The index of percentage similarity of community (PSC) (Whittaker and Fairbanks 1968) was used:

\[
PSC = 100 - 0.5 \Sigma (a-b) = \Sigma \text{min.} (a, b)
\]  

where \(a\) and \(b\) are percentages of individuals of each species in total numbers of the communities of lakes A and B, compared in pairs.

Statistical analyses were run with STATISTICA (Statsoft, Inc.) software. Probability levels of ≤0.05 were considered significant. The studies did not reveal significant differences between rotifer distribution during day and night hours (Fig. 1). Probability levels (t-test) were from \(P = 0.23\) to \(P = 0.49\) on 5/6 July and from \(P = 0.17\) to \(P = 0.88\) on 11/12 July. In all cases rotifers were concentrated in epihydroarenal, i.e. in the microlayer of the depth from 0 to 0.5 cm. During the first study day (i.e. on 5 July) 85% of rotifer community was accumulated in this layer and only 1% occurred in the adjacent water layer (Fig. 1). At night, 67% of the community inhabited 0−0.5 cm layer and 4% – adjacent water layer. However, differences between day and night distribution were not statistically significant. On the second study day (i.e. on 11 July) vertical distribution of rotifers was very similar, 64% of the community inhabited epihydroarenal and less than 1% – adjacent water layer. At night 69% of the community was found in epihydroarenal and 2% – in adjacent waters (Fig. 1).

Species structure of rotifer community was similar during day and night hours, both on 5/6 and 11/12 July (Fig. 2). However, during night hours some increase is observed of percentage of rotifers of the genus Trichocerca, mainly Trichocerca taurocephala (Hauer), and decrease of the role of bdelloids. This phenomenon was observed on both dates of the study. The strong differences between day and night structure of rotifer community in the deepest layer of endohydroarenal may be a result of very low numbers of Rotifera. Thus, occurrence of even a single individual resulted in a visible change of species structure of the community. This conclusion may be also drawn from results of a comparison of species composition of communities inhabiting particular microlayers (Table 1) by means of percentage similarity of the community index (PSC) (formula 1). The highest values of the index were observed for the microlayer 0.5 to 1.0 cm, thus the layer probably less disturbed with wave action than epihydroarenal and adjacent waters. At the same time, the lowest values of PSC were found for rotifers from adjacent water layer. The AWL communities compared in the same way with those occupying epihydroarenal (0−0.5 cm) were less similar during day (19%) than night (45%) on 5/6 July, but the phenomenon did not recur on 11/12 July, when PSC values were 23% and 19%, respectively.

Therefore, it seems that species structure of rotifer communities inhabiting upper layers of hydroarenal depends rather on stability of their environment than predation. Hence, it appears that epihydroarenal does not seem to play a role of refuge from predators for rotifers living near and close to littoral sand.
Table 1. Percentage similarity (PSC, formula 1) of the communities occupying the same microlayer (in the hydroarenal of Lake Mikołajskie) during day and night hours; AWL – adjacent water layer.

<table>
<thead>
<tr>
<th>Microlayer (cm)</th>
<th>5/6 July</th>
<th>11/12 July</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWL</td>
<td>51</td>
<td>64</td>
</tr>
<tr>
<td>0-0.5</td>
<td>67</td>
<td>90</td>
</tr>
<tr>
<td>0.5-1.0</td>
<td>89</td>
<td>82</td>
</tr>
<tr>
<td>1.0-1.5</td>
<td>71</td>
<td>88</td>
</tr>
<tr>
<td>1.5-2.0</td>
<td>79</td>
<td>66</td>
</tr>
</tbody>
</table>

Fig. 1. Vertical distribution of total rotifer density (mean ± SD) in hydroarenal of Lake Mikołajskie during day and night on 5/6 July and 12/13 July 2005. Explanations: AWL – adjacent water layer (up to 5 cm above sand bottom); EPIH – ephihydroarenal; ENDOH – endohydroarenal.
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It is evidenced by a lack of up-and-down vertical migrations of the animals and the fact that both densities and species structure of the communities inhabiting particular microlayers remain nearly unchanged during day and night hours.

On the other hand, large and permanently renewed food resources, like epiphydotsammon algae and bacteria, form there a kind of a "canteen". This suggestion may be derived from Czerńaś (1991) studies, which have evidenced that chlorophyll $a$ content is ca. 200–300 times higher in epiphydotsammon than plankton. Krupa et al. (1991) showed that concentration of chlorophyll $a$ in 0–1 cm layer of hydroarenal reaches values 2–3 times higher than in deeper layers (1–3 cm) of sand sediments. Littoral and pelagic rotifers creep although they are capable of swimming. Hence, epiphydotsammon rotifers may save energy through separation of their locomotion and feeding functions, as costs of locomotion in free-swimming rotifers are surprisingly high and may reach 62% of total metabolism, as measured by Epp and Lewis (1984) for Brachionus. This may explain the phenomenon of concentration of small benthic invertebrates in the thin microlayer between sand and adjacent water. These conclusions are in good agreement with the results of Schmid-Araya’s (1995) studies on rotifer fauna in gravel streams.

Fig. 2. Vertical changes in taxonomic composition of dominant genera of Rotifera in hydroarenal of Lake Mikolajskie during day and night on 5/6 July and 12/13 July 2005. Explanations: AWL – adjacent water layer; EPIH – epiphydotsammon; ENDOH – endohydroarenal.
The author observed that rotifers were more numerous in hyporheic interstitial at depths of higher numbers of bacteria.

Soft-bodied and small rotifers may constitute a major part of predatory and omnivorous meio- and macroinvertebrates’ diet. This type of consumers feeds rather non-selectively on prey types, especially if prey species do not differ among themselves very much in size. In physically disturbed bentic systems predation impacts and effects on the species structure of prey assemblages may be reduced (Schmid and Schmid-Araya 1997). According to Koperski (1998) littoral predators rarely drive prey population to extinction. In the presence of non-selective predators and ability of food r-strategy seems to be more profitable. Rotifers inhabiting hydroarenal are mostly small detritophageous and polyphagous species. Most rotifers have also very high population growth rate (Nogrady et al. 1993), much higher than in cladocerans and copepods. This may give another explanation for high densities of rotifers in epihydroarenal.

ACKNOWLEDGEMENTS: The research was supported by the Ministry of Education and Science, project nr 3 PO4F 020 25. I would like to thank dr. Jan I. Rybak for his help in organization of the field experiment and his assistance in the field.

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Received after revising May 2008