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Species diversity and spatial distribution of the summer rotifer assemblages in Lake Ladoga

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The rotifer assemblages of Lake Ladoga were studied in samples of the 0–10 m water layer taken at 60 sampling stations in different parts of the lake in August 1994 and 1995. In general, the species composition of the pelagial assemblages was rather similar throughout the lake. However, the dominant species differed markedly between the northern part, the central area and the Volkhov Bay. The highest species diversity (Shannon index $H' = 3.03$) and lowest wet weight biomass of rotifers (0.015 mg WW l^{-1}) were recorded in the Volkhov Bay, maximum biomass (2.53 mg WW l^{-1}) in the northern pelagic region, and lowest species diversity ($H' = 0.25$) in the northern archipelago. The filter-feeding microphagous rotifers *Conochilus unicornis* and *Keratella cochlearis* dominated most of the microzooplankton communities in the northern parts of the lake, while grasping phytophagous species of the genus *Polyarthra* predominated in the central and south-eastern parts. Species diversity, spatial distribution and the role of rotifers in the zooplankton community structure are discussed in relation to the ecological zoning of Lake Ladoga.

Introduction

Lake Ladoga is one of the most northern of the world's large lakes and the largest lake in Europe; its total surface area is 17 891 km^2, average depth 47 m, and catchment area 258 000 km^2 (Drabkova *et al*. 1996).

Dengina and Sokolova (1968) in their review of zooplankton composition in Lake Ladoga listed 200 rotifer taxa, which accounted for about 53% of the total number of zooplankton taxa recorded in the lake since 1902. More recent studies have added 20 new records of rotifers to this total (Telesh 1996). These were mainly found in the littoral area of the lake.

The great diversity of zooplankton species appears to reflect the wide range of pelagic and littoral biotopes, which differ in morphometry, presence or absence of macrophytes, productivity, trophic state and distance from pollution sources (Raspopov *et al*. 1996, Kurashov *et al*. 1996).

This study presents the results of an investigation of planktonic rotifers in the pelagic area of Lake Ladoga. The aims of the study were: (1) to update the existing species list of rotifers in the

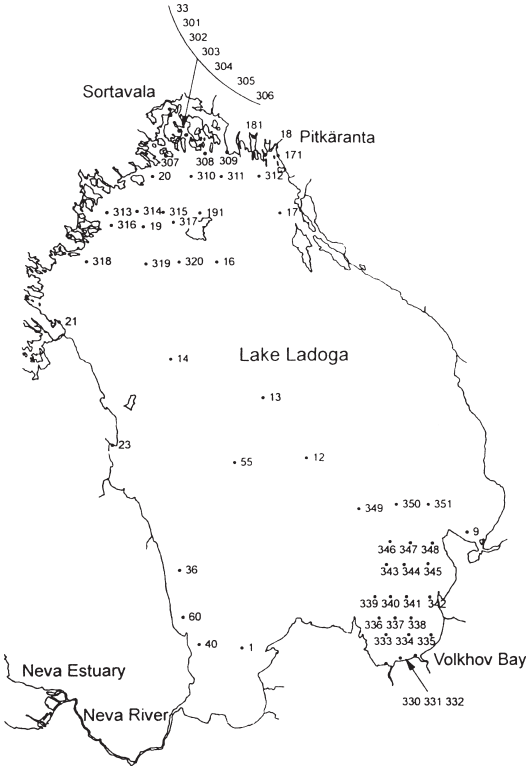

Fig. 1. Location of sampling stations in Lake Ladoga during the cruise of R/V *Talan*, August 1994.

lake, (2) to identify groups of dominant rotifers and analyse their spatial distribution within the lake, and (3) to use rotifer species diversity for the ecological zoning of Lake Ladoga.

Material and methods

Planktonic rotifers were sampled in the pelagic area of Lake Ladoga in August 1994 and August 1995. Plankton samples were taken with a plexiglass tube sampler from the 0–10 m water column at each of 60 stations (Fig. 1). The water (68–70 l) was filtered through a 50 µm mesh plankton net. The samples were preserved in 5% formalin. Species identification was made according to Kutikova (1970). Individual body masses of each rotifer species expressed as mg wet weight (WW) were calculated from average body lengths, using the formulae given by Ruttner-Kolisko (1977). Rotifer population densities at each sampling site were used for computing a Shannon-Weaver index of species diversity (H') (Shannon and Weaver 1949). Percentage share of rotifers in the total zooplankton density and biomass was also calculated for each sampling station. The rotifer species composition, distribution and abundance in the Sortavala archipelago in 1994 and 1995 were compared.

An index of dominance (D, %) was obtained for each site as the highest value of the specific dominances (D_i) calculated as:

$$D_i = (N_i/N + B_i/B)/2 \times 100, \qquad (1)$$

where N_i and B_i are the abundance and biomass of rotifer species i, respectively; N and B are the abundance and biomass of all the rotifers, respectively. Values of the index of dominance can vary between 0% and 100%.

Results

In total, about 40 rotifer species were identified during the investigation in the pelagic zone. In general, the species composition of the rotifer assemblages did not vary significantly in different regions of the lake. The most common rotifer species were usually *Conochilus unicornis* Rouss., *Keratella cochlearis* (Gosse), *Polyarthra longiremis* Carlin, *Polyarthra major* Burckhardt, *Trichocerca capucina* (Wierz. et Zach.) and *Trichocerca cylindrica* (Imhof). None of these species is typical to polluted waters; most are indicators of oligosaprobic or beta-mesosaprobic conditions (Sládeček 1973).

Among the rotifer species newly recorded in Lake Ladoga in the late 1980s (Telesh 1996), *P. longiremis* often formed dense populations in the pelagic area, especially in Volkhov Bay where it reached a maximum density of 840 ind. l^{-1}. *Keratella cochlearis* f. *tecta* (Gosse) was common though not abundant throughout the central part of the lake, reaching a maximum density of 30 ind. l^{-1} in the northern archipelago. A small population of *Notholca labis labis* Gosse (0.143 ind. l^{-1}) was observed in the open waters of the Sortavala archipelago in August 1995.

In August 1994, the total rotifer density and biomass in the Sortavala archipelago were rather

low, averaging 172 ind. l^{-1} and 0.067 mg WW l^{-1}, respectively. *K. cochlearis* dominated in numbers at Stations 301–304, *Proales* sp. at Station 33 and *C. unicornis* at Stations 305 and 306. A major part of the rotifer biomass at Station 33 and 301–304 was constituted by *Trichocerca* spp. (*T. capucina* and *T. cylindrica*), whereas at Station s 305 and 306 *C. unicornis* was dominant, as it was almost everywhere in the northern part of the lake.

In August 1995, the distribution of rotifers in the Sortavala area was more even than in August 1994, and their numerical abundance was, on average, 2 to 6 times greater. The mean total rotifer number and biomass in 1995 were 445 ind. l^{-1} and 0.446 mg WW l^{-1}, respectively. Maximum rotifer density in the Sortavala area was observed at Station 305 (480 ind. l^{-1}), but this differed little from the values at the neighbouring stations. The highest rotifer biomass was registered at the innermost part of the archipelago (Station 33: 0.551 mg WW l^{-1}); the one at the Station 305 was almost equal in value. *C. unicornis* and *Polyarthra* spp. dominated in numbers, while *Trichocerca* spp. and *Polyarthra* spp. formed the major part of the total biomass at all stations in this area.

C. unicornis strongly dominated in the northern, western and south-western regions of the lake (Fig. 2), its index of dominance was close to the maximum and reached 97.5%, while *K. cochlearis* was subdominant (Table 1). In the central area and Volkhov Bay, *Polyarthra* species usually dominated (D = 37.4%–39.4%); also *T. capucina* reached relatively high biomasses and thus played an important role in the community in these areas.

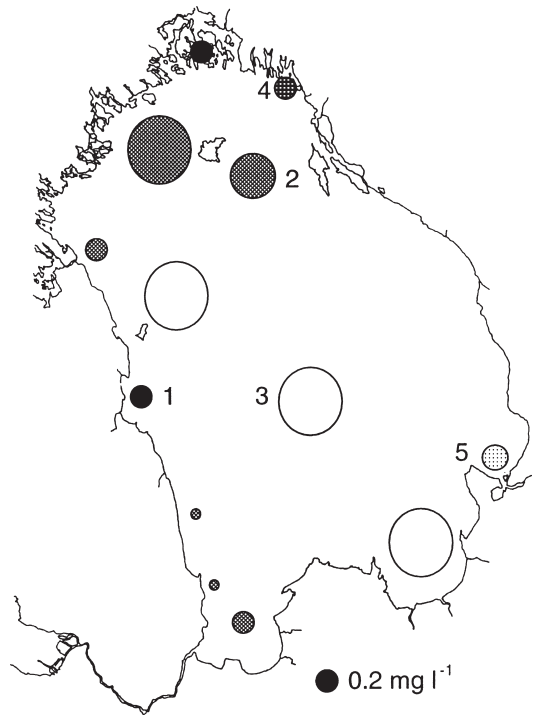

Fig. 2. Biomass of rotifers in different regions of Lake Ladoga in August 1994. Biomass values are proportional to the diameter of the circle. Dominant species indicated with hatching: 1 — *Keratella cochlearis,* 2 — *Conochilus unicornis,* 3 — *Polyarthra longiremis,* 4 — *Polyarthra vulgaris*, 5 — *Synchaeta* spp.

The numbers and biomasses of rotifers were generally high, albeit variable in August 1994 (Fig. 2), averaging for the whole Lake Ladoga at 845 ind. l^{-1} and 0.412 mg WW l^{-1}, respectively.

Table 1. Rotifer species diversity (Shannon-Weaver index, *H´*), dominant species and average index of dominance (*D*, %) for the different regions of Lake Ladoga, August 1994. For sampling stations, *see* Fig. 1.

Region	Stations	*H´*	Dominant species	*D*
NW	20, 307, 313, 318	0.68	*C. unicornis*	90.0
W, SW	1, 21, 23, 36, 40, 60	1.97	*C. unicornis*, *K. cochlearis*	43.9
N	16–19, 33, 171, 181, 191, 301–306, 308–312, 314–317, 319, 320	2.15	*C.unicornis*	47.4
Central	12–14, 55	2.43	*Polyarthra* spp.	37.4
SE (Volkhov Bay)	9, 330–351	2.47	*Polyarthra* spp.	39.4

The spatial distribution of rotifer abundance was rather irregular (Table 2).

Rotifers formed an essential component of the zooplankton community in Lake Ladoga; in some cases they accounted for 85% of the total zooplankton biomass, as was observed in the north-western area of the lake. There, (Station 318) the highest rotifer density for Lake Ladoga was recorded, 6 737 ind. l^{-1}, which is equivalent to a biomass of 2.528 mg WW l^{-1}. Highest species diversity was observed in the near-shore area of Volkhov Bay (Station 331, $H' = 3.03$), and the lowest species diversity in the northern archipelago (Station 307, $H' = 0.25$). There was no statistically significant correlation between rotifer biomass and species diversity in Lake Ladoga.

In the pelagic area of the lake, the average species diversity was not very high ($H' = 2.12$, $n = 60$). By taking into account the spatial distribution of rotifer assemblages, species dominance and index of species diversity, several zones in Lake Ladoga could be distinguished (Tables 1 and 2). The highest values of rotifer species diversity were observed at the sampling sites located close to the Volkhov River mouth, which can be characterized as rather polluted (Drabkova *et al.* 1996) and eutrophic area (Holopainen *et al.* 1996).

Table 2. Mean (and range) of rotifer density (*N*, ind. l^{-1}) and biomass (*B*, mg WW l^{-1}) in different pelagic regions of Lake Ladoga and averages for the whole lake. *n* = number of observation stations.

Region	*N*	*B*	*n*
NW	2 480 (297–6 737)	0.949 (0.127–2.528)	4
W, SW	299 (70–448)	0.095 (0.032–0.220)	6
N	382 (75–1080)	0.142 (0.030–0.355)	25
Central	552 (147–1057)	0.452 (0.177–0.728)	4
SE	511 (32–1138)	0.421 (0.015–1.167)	21
Lake average	845	0.412	60

Discussion

Rotifers as a component of zooplankton communities in Lake Ladoga have been studied since the early 20th century. However, the first numerical data on zooplankton in the lake was not published until the middle of the century (Sokolova 1956). Although rotifers were known to play an important role as indicator species in assessment of water quality as well as eutrophication (Smirnova 1987, Andronikova 1996), no special studies on rotifers in Lake Ladoga had been conducted until recently.

Smirnova (1982) showed that rotifers constituted maximally 74% of the total zooplankton density and 34% of the total zooplankton biomass in Lake Ladoga in August 1976. However, in those studies rotifers were counted in samples collected with a Juday plankton net with a mesh size of 100–120 μm, a method which provides serious under-estimation of the density of rotifer populations (Telesh 1986). The more precise sampling method used in the present study indicated very high maximum values for the share of rotifers in the total zooplankton (up to 85% of biomass in August 1994). On average, the biomass share of rotifers was 20% in Lake Ladoga. This value is similar to those recorded in the 1980s with the same sampling method in Lake St. Clair (24%) and Lake Erie (20.8%), but higher than the corresponding figures for the other Great Lakes in North America: Huron (7.1%), Ontario (5.1%) and Superior (0.6%) (Sprules and Munawar 1991).

Rotifer species diversity is rather high in Lake Ladoga. However, most of the rotifer species that have been newly found in the littoral areas of Lake Ladoga (Telesh 1996) were not registered in the pelagic part of the lake during the present study. The fact that both the pelagic dominants of the northern and central areas, *Conochilus unicornis* and *Keratella cochlearis*, are microphagous species feeding mainly on detritus with associated bacteria, while *Polyarthra longiremis*, dominant in the SE, preferably consumes cryptomonads (Pourriot 1977), indicates differences in the trophic structure of the pelagic communities between the northern and central areas and in the Volkhov Bay.

Generally, species diversity within aquatic communities is closely related to the trophic state of the waterbody. Earlier, Gilyarov (1969) and Alimov (1990) have demonstrated an inverse relationship between species diversity and biomass of different groups of planktonic and benthic invertebrates in lakes. Nevertheless, no statistically significant correlation could be established between rotifer biomass and species diversity in the pelagic areas of Lake Ladoga in the present study.

The Shannon-Weaver index of species diversity for the whole zooplankton community tends to decrease as a waterbody becomes more eutrophic (Andronikova 1996). Also, eutrophic waters are usually characterized by a dominance of small planktonic organisms (Andronikova 1980). These views are supported by the present study which found a high diversity of microplanktonic rotifers in the more eutrophic areas of Lake Ladoga (Volkhov Bay) compared to less eutrophic regions, following the classification of the trophic state of the lake indicated by the late summer phytoplankton (Holopainen *et al.* 1996). This result highlights the importance of rotifer assemblages as indicators for the monitoring of eutrophication in Lake Ladoga.

The low species diversity of rotifers at northwestern Station 318 ($H´ = 1.04$), connected with high abundance of *Conochilus unicornis*, can hardly be taken as evidence of a high degree of eutrophication in this area. Surface water chlorophyll *a* concentration at Station 318 varied in the range 2.2–4.4 $\mu g\ l^{-1}$ in August 1993, which corresponds to mesotrophic conditions (Holopainen *et al.* 1996). The observed incidence of low rotifer diversity may reflect a temporary (seasonal) situation in the trophic structure of the pelagic community.

In some northern areas of the lake, filter-feeding microphagous rotifers constitute up to 85% of total zooplankton biomass and play a significant role in the trophic structure and functioning of pelagic communities. The species diversity of rotifers was highest in more eutrophic areas of the lake. Rotifer species diversity, the trophic structure of their assemblages and spatial distribution can be used as criteria for the evaluation of environmental heterogeneity and of the complexity of pelagic communities in Lake Ladoga.

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