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Comparison of Pelagic Rotifer Communities in Three Natural Macedonian Lakes

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Abstract: The pelagic rotifers in three natural Macedonian lakes: Lake Ohrid, Lake Prespa and Lake Dojran in the period 2004–2006 were investigated. Qualitative analyses of rotifer composition in them showed presence of 11, 8 and 17 taxa, respectively. Rotifer assemblages differed in their community structure, population density and the occurrence pattern of dominant species. The density of rotifers increased with increasing nutrient concentration. Their mean annual density in the Lake Ohrid was 93 ind m^{-3}, in the Lake Prespa was 2097 ind m^{-3}, whereas in the Lake Dojran it was 11665 ind m^{-3}. *Gastropus stylifer* and *Keratella cochlearis* were the most abundant species in the pelagic zone of Lake Ohrid. In the pelagic zone of Lake Prespa, *Keratella quadrata* and *Filinia longiseta* were the most abundant species. Contrary, in the pelagic zone of Lake Dojran, the rotifer species assemblage was dominated by *Brachionus* spp. *B. diversicornis* and *B. calyciflorus* f. *amphiceros* were the most abundant species. The vertical distributions of rotifers in the lakes were related to both biotic and abiotic variables. These results demonstrated the relationships between the number of structural characteristics of rotifer species and the trophic state of the investigated lakes.

Key words: Lake Ohrid, Lake Prespa, Lake Dojran, rotifers, structural characteristics, trophic state

Introduction

Rotifers form the essential structural and functional component of pelagic communities and constitute an important part of the freshwater zooplankton. They easily adapt to changes in environmental conditions, and it is therefore difficult to establish a constant level of composition and occurrence of a species in specific areas at specific times.

Inventories of rotifers are important for evaluating environmental changes and understanding functional properties of freshwater ecosystem (Bledzki, Ellison 2003).

The studies of rotifers were undertaken to identify the species structure and abundance, occurrence pattern of dominant species in relation to certain environmental factors and to compare the rotifer communities in three natural Macedonian lakes (Ohrid, Prespa and Dojran) of different trophic status: oligotrophic, mesotrophic and eutrophic, respectively.

Material and Methods

The study is based on monthly collections made from 2004-2006 in the pelagic zone of Lakes Ohrid, Prespa and Dojran. Samples were collected with 5-L Ruttner sampler, filtered *in situ* through a sieve (45 μm mesh-size) and preserved with 4% formaldehyde. Identification of species was made according to identification guides (Kutikova 1970, Koste 1978, Segers 1995).

The Jaccard similarity coefficient (*J*) (Patalas, Salki 1992) was used to compare community structures between the lakes. Prior to the statistical analysis, data normality was checked using Shapiro–Wilk's test. As this test suggested that the data did not follow a normal distribution, a nonparametric Kruskal–Wallis test (comparison among multiple independent samples for distribution and density of rotifers in different seasons and different lakes) was used. Spearman correlation tests were used to

analyze the linkage between dissolved oxygen and rotifer abundance. The statistical analyses were performed with the STATISTICA 8.0 (Statsoft Inc. 2007) analyses package.

The following limnochemical and physical parameters were also analyzed: temperature, dissolved oxygen, Secchi transparency (Bether 1953), total nitrogen (Solorzano 1969) and total phosphorus (Strickland, Parsons 1972).

Results and Discussion

Despite the fact that the rotifer fauna is the most diverse component in the composition of Lake Ohrid zooplankton, still, the number of the pelagic species of rotifer is relatively poor. During our investigations there have been registered only 11 species adapted to the especially planktonic life: *Asplanchna priodonta* Gosse 1850, *Conochilus hippocrepis* (Schrank 1803), *Filinia terminalis* (Plate 1886), *Gastropus stylifer* Imhof 1891, *Kellicottia longispina* (Kellicott 1879), *Keratella cochlearis cochlearis* (Gosse 1851), *Keratella quadrata* (Müller 1786), *Ploesoma truncatum* (Levander 1894), *Polyarthra vulgaris* Carlin 1943, *Synchaeta stylata* Wierzejski 1893 and *Trichocerca capucina* (Wierzejski et Zacharias 1893). The vast number of them is also detected in the free water of the littoral zone. Serafimova-Hadzishce (1957) in her investigations from the period 1952-1954 describes only 8 rotifer species in the zooplankton community. On the other hand, Kostoski (1998) discuss 12 species. Moreover, the species *Hexarthra mira* registered as a new species in the composition of the zooplankton of Lake Ohrid (Kostoski 1998), has been noted only in the free water in some localities of the littoral during our researches.

In Lake Prespa have been registered 13 planktonic species with quite similar qualitative composition with Lake Ohrid (Serafimova-Hadzishce 1958, Shumka 1994). During our researches in the pelagic zone of the lake, there have been registered only 8 planktonic species: *Asplanchna priodonta*, *Filinia longiseta* (Ehrenberg 1834), *Gastropus stylifer*, *Kellicottia longispina*, *Keratella cochlearis cochlearis*, *Keratella quadrata*, *Polyarthra vulgaris* and *Trichocerca capucina*.

In the pelagic zone of Lake Dojran in the period 1954–1961 were registered 22 species of Rotifera (Popovska-Stankovic 1990), while in the period 1997-1998 were described only 19 of them (Popovska-Stankovic 2001). During our researches there have been registered total of 17 species: *Anuraeopsis fissa fissa* Gosse 1851, *Asplanchna sieboldii* (Leydig 1854), *Brachionus calyciflorus* f. *amphiceros* Ehrenberg 1838, *Brachionus diversicornis diversicornis* (Daday 1883), *Brachionus diversicornis* f. *homoceros* (Wierzejski 1891), *Filinia longiseta*, *Keratella cochlearis cochlearis*, *Keratella cochlearis tecta* (Gosse 1851), *Keratella qadrata quadrata*, *Keratella tropica* (Apstein 1907), *Polyarhra euryptera* Wierzejski 1891, *Polyarthra major* Burskhardt 1900, *Polyarthra vulgaris* Carlin 1943, *Pompholyx complanata* Gosse 1851, *Trichocerca capucina*, *Trichocerca pusilla* (Jennings 1903), *Trichocerca (D.) similis similis* (Wierzejski 1893).

However, owing to unavoidable methodological differences, the documentation of the disappearance and appearance of different species should be always considered with some caution when comparing the results of different investigations.

The dynamics of the present species in the pelagic regions of all researched lakes has considerable seasonal character: seasonal appearance of some species or seasonal hesitations of their population density. In the period 2004-2006, the populations of rotifers attain the greatest abundance in the summer-autumn period of the year. Still, the quantity of the populations varies in different years, which can be seen in Fig. 1, 2 and 3. Results of Kruskal–Wallis test for 2004, 2005 and 2006 for Ohrid ($H = 37.16$, $n = 60$, $p = 0.0001$), Prespa ($H = 42.95$, $n = 80$, $p = 0.0002$) and Dojran ($H = 19.33$, $n = 36$, $p = 0.0017$) showed significant differences in the number and abundance of the species in regards to the researching year. Different authors point out that the rapid increase in rotifer numbers may be attributed to their intrinsic high fecundity, supported by favorable food and environmental conditions (Dumont 1977, Gulati 1999). On the other hand, the low density of the rotifers during the cold period of the year can be as a result of the low temperatures that are obstacle for their development, growth and reproduction (Michaloudi *et al*. 1997).

The results obtained by the previous research (Tasevska 2002) and the review of the long-term investigations (Tasevska *et al*. 2008) indicated that the species *Kellicottia longispina* and *Keratella cochlearis* have been dominant in the plankton of Lake Ohrid and have provided the main characteristic of the entire community of rotifers in the lake. However, during the period 2004-2006, the greatest

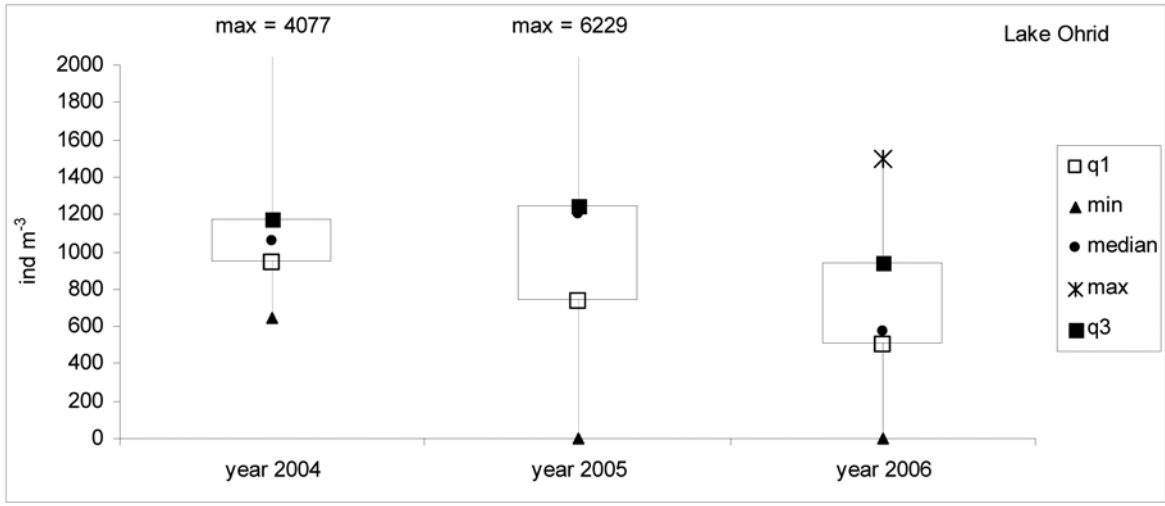

Fig. 1. Box–plots of the species density in regards to the researching year in Lake Ohrid pelagic zone.

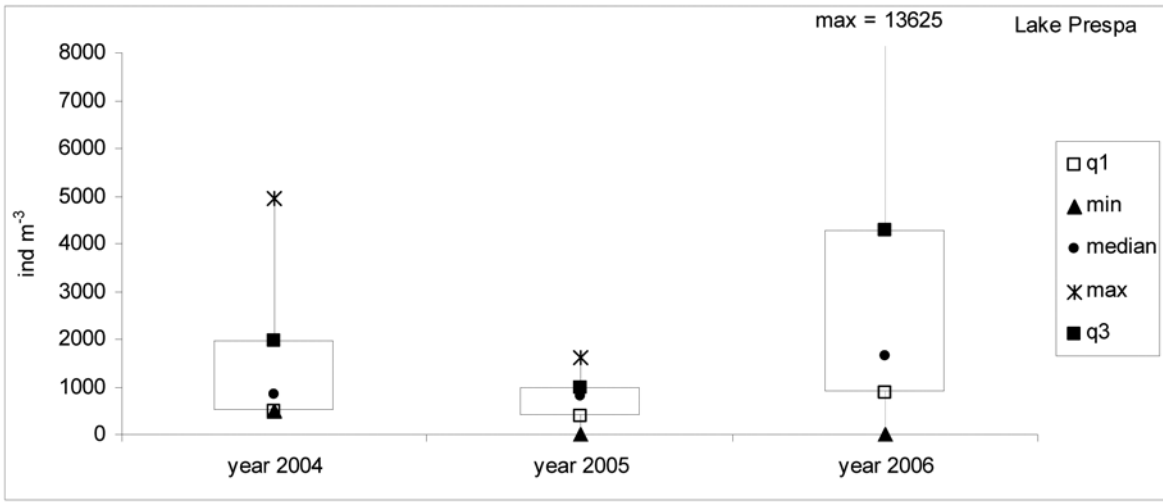

Fig. 2. Box–plots of the species density in regards to the researching year in Lake Prespa pelagic zone.

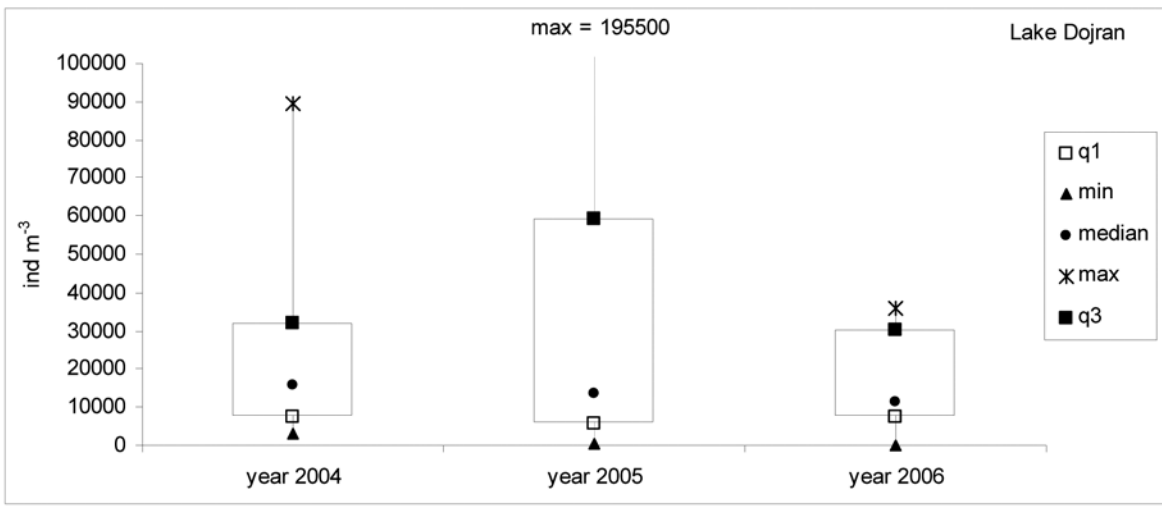

Fig. 3. Box–plots of the species density in regards to the researching year in Lake Dojran pelagic zone.

average density is attained by *Gastropus stylifer*, contributing 28% to rotifer abundance. Although this species is registered as a summer form (Serafimova-Hadzishce 1957), in the pelagic zone of Lake Ohrid it is present throughout the year.

The composition of the pelagic community of rotifers from Lake Prespa is almost identical to the composition of this community in Lake Ohrid (J = 0.58). This condition has been expected, knowing the mutual origin of the lakes, as well as the geographical, or hydrological link between the lakes, i.e. the natural inflow of water from Prespa in Ohrid (Anovski *et al*. 1980, Zoto *et al*. 2004). However, there have been registered some differences, too. In Prespa *Filinia longiseta* is present, while in Ohrid is *Filinia terminalis*. The presence of *Filinia terminalis* in Lake Ohrid is conditioned by the more favourable conditions for its development, since it is defined as cold stenotherm species, which is adapted to greater concentrations of oxygen (Berzins, Pejler 1989, Duggan *et al*. 2001). Also, the species *Ploesoma truncatum*, which exists in Ohrid, during our researches, has not been registered in Prespa, despite the fact that it used to be registered by Serafimova-Hadzishce (1954) and Shumka (1994).

Besides the differences in the composition, there should be mentioned the differences in the population density as well. Thus, the average density of the rotifer population in Lake Ohrid in 2004 was 103 ± 150 ind m^{-3}, in 2005 was 115 ± 135 ind m^{-3}, while in 2006 was 61 ± 59 ind m^{-3}. For Lake Prespa the average densities were 1561 ± 1463 ind m^{-3}, 738 ± 411 ind m^{-3} and 3594 ± 4379 ind m^{-3}, in 2004, 2005 and 2006, respectively, which indicates to greater productivity in this lake in comparison to Ohrid. As a supportive argument is also the fact that the density of the phytoplankton is much greater in Prespa in comparison to Ohrid and during the summer period it attains even above 2 000 000 ind l^{-1} (Patceva 2005). As a common zooplankter in lakes major food resources for rotifers are algae, protists and bacteria (Pourriot 1977, Arndt 1993, Ooms-Wilms 1997). As these food resources are generally more abundant in nutrient-rich environments, rotifer abundance is expected to rise with increased lakes productivity.

The greatest participation (40%) in this high density of rotifers in Lake Prespa has the species *Keratella quadrata*. The species *Filinia longiseta* shows stability in the appearance and presence, comprising 21% of total rotifer density.

The natural conditions predetermined with the origin and the geographical situation, as well as the anthropogenic factors results Dojran to be characterized with somewhat different composition of rotifer fauna ($J_{O,D}$ = 0.17; $J_{P,D}$ = 0.25): a predominance of periphytic or littoral elements and fewer plankton rotifers. This important feature can be assigned to the lack of definite pelagic habitat (De Manuel 1994), its shallow nature and growth of aquatic macrophytes (Sharma, Sharma 2001). In the pelagic zone of Lake Dojran, the rotifer species assemblage was dominated by *Brachionus* spp. *Brachionus diversicornis* and *Brachionus calyciflorus amphiceros* were the most abundant species, comprising 40% and 25% of total rotifer density. Fam. Brachionidae frequently provides a significant number of individuals and species to the rotifer community from the reservoirs (De Manuel 1991), while many authors link it with waters with greater degree of trophic status (Sladecek 1983, Matveeva 1991). The average density of rotifer population in Dojran was 7252 ± 3434 ind m^{-3} in 2004, 12 935 ± 3689 ind m^{-3} in 2005 and 9073 ± 16 890 ind m^{-3} in 2006.

In regards to the vertical distribution of rotifers in the water column of Lake Ohrid, the greater part of the species was distributed in the layers from 10 to 40 m depth. This is conditioned with the physical and chemical conditions which prevail in the lake. The maximum densities of the populations in the trophogenic zone coincide with the favorable temperature conditions, the high concentration of oxygen (from 10 to 13 mg L^{-1}), greater quantities of dissolved organic material and certainly, greater phytoplankton production, mainly in the layers between 10 and 40 m (Patceva 2005). Analyzing Spearman correlation test it is concluded that oxygen ($r = 0.55$, $P < 0.05$) positively influenced rotifer density in the Lake Ohrid pelagic zone. According to many authors, the temperature and oxygen are among the most important environmental factors acknowledged to explain the space-time fluctuations of rotifer populations (Mikschi 1989).

In Lake Prespa, the rotifers are distributed along the entire water column, which certainly is as a result of the small depth of this lake. However, the greatest density of the population is attained in the surface, up to 5 m depth. One of the main reasons for this distribution of rotifers is the phytoplankton density, which attains its maximum average in the surface waters and in depths of 5 m. From 5 to 10 m, the density is gradually decreasing while near the bottom

it is substantially decreased (Patceva 2005). In addition, according to our researches, the concentrations of oxygen in the layers with greater depth, during the summer period decrease even down to 1.22 mg L^{-1}. This fact can be one of the constraining factors for the vertical distribution of the species. Dissolved oxygen also significantly correlated with the abundance and diversity of rotifers in Prespa ($r = 0.56$, $P < 0.05$) and Dojran ($r = 0.74$, $P < 0.05$) pelagic zones. The concentration of oxygen is a relevant factor not only for the deep and stratified lakes, but also for the other types of lakes and waters, when the abundance of the rotifers is analyzed (Esparcia *et al*. 1989).

In Lake Dojran, the quite low depth of merely 4 m, have conditioned distributions of the species from the surface to the bottom. Since the absence of thermal stratification reduces the influence of abiotic processes on spatial distribution, the degree of vertical aggregation in homothermic environments may be better explained by biotic factors such as food availability (Bini *et al*. 2001). In Dojran, rotifers attain the greatest density in the surface, down to 1.5 m of depth, which is in accordance to the small transparency from 0.5 to 0.7 m during summer, as well as with the vertical distribution of the chlorophyll *a*, which has its maximum concentrations in the surface waters (Temponeras *et al*. 2000). Devetter, Sed`a (2003) have proven that the rotifer fecundity depends on chlorophyll *a* concentration.

The quantity and quality of food have significant effect on average lifespan, reproductive rate, and generation time and population growth rate (Jensen, Verschoor 2004, Weithoff 2007, Strojsova *et al*. 2008). In the composition of the phytoplankton community of Ohrid and Prespa there is a great difference. In Lake Prespa, Cyanophyta and Bacillariophyta play the main role in the phytoplankton, contributing to approximately 95% of the entire biomass of the phytoplankton, with quite small percentage contribution of the other types of algae. This type of presence of the mentioned algae is characteristic of lakes that are in a process of eutrophication. In Lake Ohrid, Crysophyta, Chlorophyta and Pyrrophyta play very important role in the phytoplankton, while Cyanophyta and Bacillariophyta are contributing with 65% of the phytoplankton biomass (Patceva 2005). It cannot be claimed with great certainty which of these groups contributes with the greatest percent in the nutrition of rotifers; however, following the maximum of the development of the phytoplankton there is a maximum development in the populations of rotifers, too. The situation with Lake Dojran is completely different. The decrease of the level of the water in the lake and the changes in the ecological parameters has resulted in reduction of the quality of the composition of the phytoplankton, too. In addition, all these factors have resulted in a mass development of certain taxa, great number of diatoms, as well as potentially toxic species from Cyanophyta. Even though algae of Cyanophyta have a negative effect on the development of the rotifers, some species, such as *Brachionus calyciflorus* have a great ability to utilize colonial Cyanophicae as food, exhibit a great tolerance to their blooms (Fulton, Pearl 1987), so that they become abundant in such conditions and may be considered bioindicators of eutrophication (Sampaio *et al.* 2002).

The comparison of the rotifer communities of three natural Macedonian lakes (Ohrid, Prespa and Dojran) showed that rotifer assemblages differed in their community structure, population density and the occurrence pattern of dominant species. There were statistically significant differences among different lakes in the abundance of the dominant rotifer species, *Brachionus* sp. (Kruskal–Wallis test H 20.59, $n = 36$, $p = 0.0001$), *Keratella quadrata* (Kruskal-Wallis test $H = 11.56$, $n = 36$, $p = 0.0031$), *Gastropus stylifer* (Kruskal-Wallis test $H = 12.24$, $n = 36$, $p = 0.0022$) and total rotifer abundance (Kruskal-Wallis test $H = 55.86$, $n = 360$, $p = 0.0001$).

The size of the water bodies (Patalas 1971) their trophic state (Gannon, Stemberger 1978) and the succession stage (Hutchinson 1967) greatly influence the species composition of the zooplankton. In natural environments all mentioned factors act simultaneously and may also interact to different degrees, modifying the zooplankton structure in different ways.

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