Review Article

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Biomass Dynamics of Pelagic Crustacea in Lake Ohrid, Republic of Macedonia, in the Period 2000–2009

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Abstract: The trends in biomass dynamics of the Crustacea (Cladocera and Copepoda) in the pelagic zone of Lake Ohrid were analysed through the period 2000–2009. The Copepoda contributed to the total Crustacea biomass by a major ratio. The values of the Crustacea biomass were the highest in the summer and autumn periods, when the values of the Copepoda and Cladocera biomass were similar. Considerable increase in the Crustacea biomass was recorded during the summer period 2004, which resulted from the relatively high biomass values of the Copepoda, especially the Calanoida. High values of the Crustacea biomass were found also in the summer and autumn period 2008–2009, when the biomass of the Cladocera considerably increased in comparison with the other studied periods that imply considerable changes in zooplankton community.

Key words: Lake Ohrid, pelagic zone, zooplankton, Copepoda, Cladocera, biomass

Introduction

The long-term zooplankton investigations in Lake Ohrid (Serafimova-Hadžišče 1957, 1958, 1959, 1986, Kostoski 1993, 1998, Guseska 1998, 2003, Guseska et al. 2003, 2007, 2013) have confirmed certain changes in the zooplankton community.

In the last few decades Lake Ohrid has been subjected to permanent anthropogenic impact. Evidences of high pollution degree and eutrophication in the littoral area have been reported (Patceva et al. 2004, Jordanoski et al. 2005, Lokoska 2015). The negative influence has eventually spread into the pelagic zone. Kostoski (1998) and Guseska et al. (2003) reported the presence of two allochthonous species of Cladocera: *Diaphanosoma birgei lacustris* (Korinek) and *Leptodora kindtii* (Focke), which indicates instability in the plankton community.

The biomass of pelagic Crustacea in Lake Ohrid has been monitored for different periods (Guseska et al. 2004, 2006, 2010, 2013). In this paper, we review available data and findings for the period 2000–2009, in order to determine the trends in the Crustacea biomass dynamics and changes in zooplankton community.

Materials and Methods

Lake Ohrid (N41˚2′19″, E20˚44′13″) is located in the south-western part of the Republic of Macedonia. It is the oldest lake in Europe, with an estimated age from 1.9 to 1.3 million years (Wagner et al. 2017). The lake is oligotrophic, and has a maximal depth of 288.7 m, a surface area of 358 km^2 and water volume of 54.9 km^3 (Matzinger et al. 2007). It is an oligomictic lake; a complete mixing occurs once in a decade (Hadžišče 1966).

The results were based on the analysis of material collected monthly during the period 2000–2009 from the lake pelagic zone at one stationary point, with a maximum depth of 245 m.

The samples were taken with a 5–litre Ruttner

sampler at the following depths: 0 m, 10 m, 20 m, 30 m, 40 m, 50 m, 75 m, 100 m, and 150 m. They were filtered *in situ* through a sieve (55 μm mesh-size) and preserved with 4% formalin. The water temperature was measured at each sampling depth.

The zooplankton material was analysed quantitatively on the Utermöhl chamber, under an inverted Hydro–Bios microscope (100× to 600×).

The biomass (dry weight, $\mu g\ m^{-3}$) was calculated from individual body length measurements on each sample, by applying length/ weight regression equations (Bottrell et al. 1976). Water temperature on the vertical profile was recorded using ProfiLine pH/mV–Meter pH 197 up to the depth of 50 m, during the period 1996–2009.

The analyses of trends in the biomass dynamics of the Crustacea (Copepoda and Cladocera) were based on the review of available data from our previous studies (Guseska et al. 2004, 2006, 2010, 2013).

Results

The results of the measured water temperature are presented in Figures 1, 2 and 3. The mean summer temperatures of the upper water layers in the period 2007–2008 were higher in comparison to the previous studied years.

The following species of Copepoda were recorded in the Lake Ohrid pelagial in the period 2000–2009: *Eudiaptomus gracilis* (Sars, 1863); *Arctodiaptomus steindachneri* (Richard, 1897), an endemic species for the western part of the Balkans, with limited distribution area in the lakes Ohrid, Prespa and Janina (Kiefer & Fryer 1978); *Cyclops ochridanus* (Kiefer, 1932), an endemic species for Lake Ohrid; and *Mesocyclops leuckarti* (Claus, 1857) (Guseska et al. 2004, 2006, 2010).

For the same period 2000–2009, the following species of Cladocera were found: *Daphnia pulicaria* (Forbes, 1893) and *Bosmina longirostris* (O. F. Müller, 1785), which were present in the pelagial all the year round; as well as the two allochthonous species *Diaphanosoma birgei lacustris* (Korinek, 1981) and *Leptodora kindtii* (Focke, 1844), which were present in the summer and autumn period (Guseska et al. 2006, 2010, 2013).

The biomass oscillations in Crustacea: Copepoda and Cladocera in the pelagic zone of Lake Ohrid, in different periods, are presented in Figures 4, 5 and 6. It is evident that the total Crustacea biomass in spring, summer and autumn was much higher than in winter.

During 2000, the Copepoda were dominant,

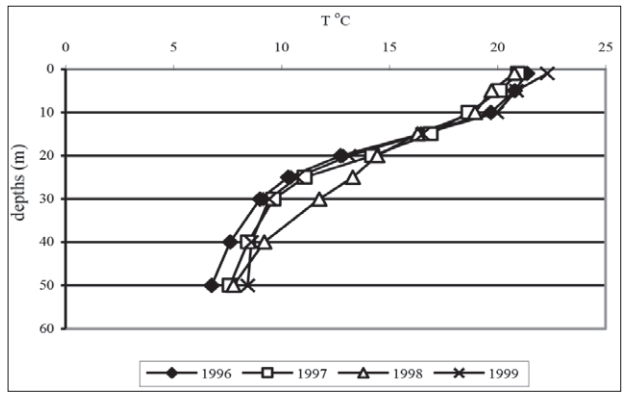

Fig. 1. Mean summer temperatures (T, °C) at different depths in the pelagic zone of Lake Ohrid, during the period 1996–1999

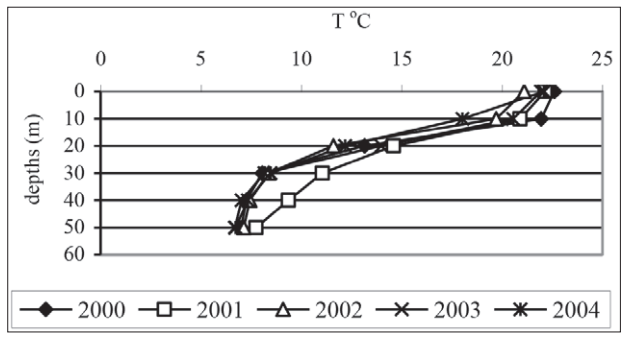

Fig. 2. Mean summer temperatures (T, °C) at different depths in the pelagic zone of Lake Ohrid, during the period 2000–2004

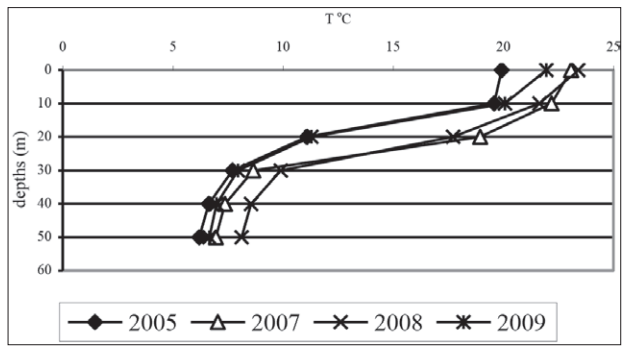

Fig. 3. Mean summer temperatures (T, °C) at different depths in the pelagic zone of Lake Ohrid, during the period 2005–2009

with an exception of the summer and autumn period when similar values of the Copepoda and Cladocera biomass were recorded. The highest average value of the Copepoda biomass was registered in August 2000, while the highest average value of the Cladocera biomass was registered in September 2000 (Guseska et al. 2004, 2013) (Fig. 4).

In summer and autumn 2004, there was a considerable increase in the total biomass within the Crustacea community, which resulted from the high

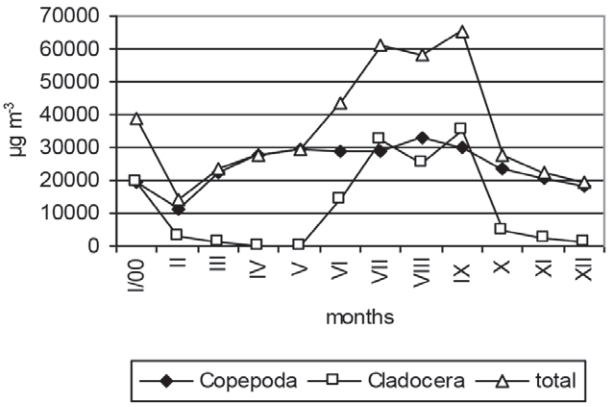

Fig. 4. Oscillations in average biomass (µg m^{-3}) of pelagic Crustacea in Lake Ohrid, during 2000

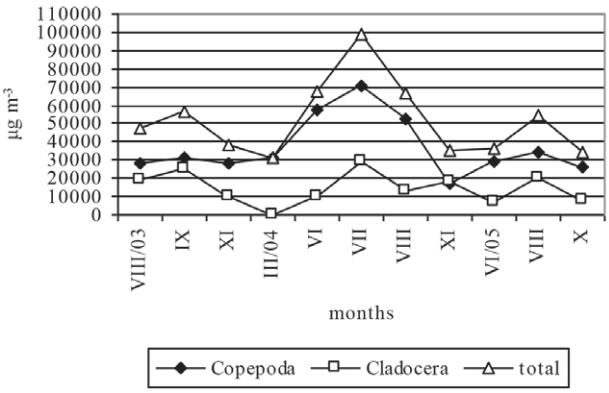

Fig. 5. Oscillations in average biomass (µg m^{-3}) of pelagic Crustacea in Lake Ohrid, during 2003–2005

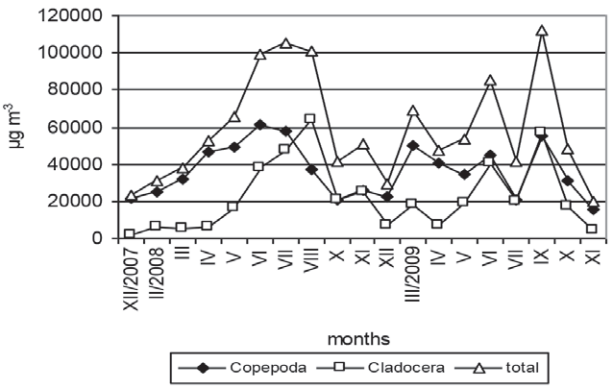

Fig. 6. Oscillations in average biomass (µg m^{-3}) of pelagic Crustacea in Lake Ohrid, during 2007–2009

biomass values of the Copepoda, especially of the Calanoida. Copepoda, in comparison to Cladocera, contributed with more than 70% to the total biomass and reached the highest average value in July 2004 (Guseska et al. 2006, 2013) (Fig. 5).

In summer and autumn 2008, there was a considerable increase in the biomass of the Cladocera (the highest average values reached in August 2008). Dominant species were *D. pulicaria* and *D. birgei lacustris*. Considerable high values of the Cladocera biomass were observed in summer and autumn 2009, with the highest average value in September 2009 (Guseska et al. 2010, 2013) (Fig. 6).

Discussion

The Copepoda were dominant in the Crustacea biomass throughout the whole studied period (2000–2009), which determines Lake Ohrid as a Copepoda-dominated lake. The dominance of Copepoda indicates good trophic conditions, i.e. an oligotrophic character of the lake (Blancher 1984). Gannon & Stemberger (1978) found that the Calanoida dominate in oligotrophic communities, and the Great Lakes, where the Calanoida density comprises over 50% of the summer crustacean zooplankton community, may be classified as oligotrophic. The proportion of the Calanoida in Lake Superior has remained fairly stable at 70%, indicating oligotrophic conditions (Environment Canada and the U.S. Environmental Protection Agency 2014).

In the winter and spring period, the greatest contribution to the Copepoda biomass had the species *E. gracilis* and *C. ochridanus* (females, males, ovigerous females), and larval stages, indicating intensive reproduction. High values of biomass in this period were recorded for *A. steindachneri* (larval copepodid stages IV and V). They are active in the plankton, but their development stagnates because of low temperatures (Guseska 2003). The dominance of Copepoda in the winter and spring and the summer and autumn periods is related to water temperature and nutrition (Guseska 2003). In Lake Ohrid, the diatoms of the genus *Cyclotella* are dominant in the phytoplankton, during the winter and early-spring periods (Mitic 1990, Mitic & Patceva 2001, Patceva 2001). According to Beklemishev (1954), the diatoms contribute with the highest percentage to the nutrition of *E. gracilis* and are very important for the maturation of eggs and the development of the larvae. Czeczuga & Kozłowska (2002) pointed out that in six investigated lakes in the Suwalki District, Poland, in winter, Copepoda representatives can be found mainly as copepodidal forms, which feed on diatoms found abundant in the lakes in that season.

Higher values of the Copepoda biomass were registered in the summer and autumn period, owing to the high values of *A. steindachneri* and *M. leuckarti* (females, males, ovigerous females), as well as the different larval development stages as a result of intensive reproduction. A considerable contribution

to the biomass was also due to the larval copepodid stages IV and V of *E. gracilis* and *C. ochridanus*.

Although the Cladocera have considerably smaller density with regards to Copepoda, taking into consideration their individual biomass, they contribute substantially to the total biomass of the Crustacea. High biomass values have been registered in the summer and autumn periods, when in addition to the autochthonous species *D. pulicaria* and *B. longirostris*, the two allochthonous species occurred: *D. birgei lacustris* (present with higher abundance) and the predator *L. kindtii*. According to Mourelatos & Lacroix (1990), the high maximum of the Cladocera in the summer–autumn periods could be the result of the increased food availability, as well as the increase in temperature. Visconti et al. (2008) reported that zooplankton population density and biomass in Lake Lago Maggiore sharply increased in 2003, which was the warmest year in the period of the author's study, as a result of the Cladocera domination, particularly *Daphnia*, attaining values typical for the mesotrophic state.

In Lake Ohrid, according to our results, the mean summer temperatures of the upper water layers were higher in the period 2007–2008 compared to the previous years of study. During the summer months, the chlorophyll *a* concentration is high, especially in the surface layer, due to the maximum growth of phytoplankton (Patceva 2001). In the same period, the Cladocera are most abundant in the upper layers, and thus, contribute to the increase in the total biomass of the Crustacea. The high quantitative presence of *D. pulicaria* and *D. birgei lacustris* imply considerable changes in zooplankton community in the Lake Ohrid pelagial.

Despite the changes registered during our study, the dominance of the Copepoda biomass throughout the whole studied period indicates that Lake Ohrid maintains a good trophic status, i.e. the lake is oligotrophic.

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