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ZOOPLANKTON COMMUNITY STRUCTURE OF THE FISH FARM NAGĻI (LATVIA)

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The community structure of zooplankton and its changes in lakes and ponds indicate the interaction of abiotic and biotic factors in them. In the fish farm Nagļi (Latvia) zooplankton community structure studies were based on the biotic parameters (predatory, competition) and analysis of the impact of environmental factors. Ponds studied are artificially created; located in one place, very shallow and take up a small area from ~ 0.80 ha to ~ 0.35 ha, are separated from one another, with one water supply and the water level is maintained by a flow. This study was conducted in May and July 2018, using appropriate standard methods for hydrobiological field and laboratory investigations. Although ponds are very similar, it was found out that the community structure of zooplankton differs both by taxonomic composition, abundance and biomass, in some ponds dominants are crustaceans (Cladocera, Copepoda), rotifers and copepods or only rotifers. The community structure of zooplankton indicates a predator, interspecies competition and "bottom up" control in fish ponds Nagļi (significant correlation between chlorophyll α concentration and rotifers biomass). In overall, ponds correspond to eutrophic waters either with clearer water or with turbid water state.

Key words: zooplankton, community structure, fish ponds, biotic abiotic interactions.

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INTRODUCTION

Zooplankton is one of the first food sources in fish development in both natural water and aquaculture. In the early stages of development fish begin to feed on small-sized rotifers first. When they grow, they switch to feeding on larger-sized copepods and cladocerans; in further lifetime zooplankton remains an important part of their diet (Nunn et al. 2012, Anton-Pardo, Adámek 2015). Various studies of gut content analysis depending on fish age or size and weight show that the proportion of zooplankton in the fish diet varies from 0% to 90%. In fish of different ages, raised in polyculture, rotifers varies from <0.5% to 2.4%, cladocerans from 5.3 to 65%, copepods from 0.3 to 74% in the gut content of carp, but in the tench gut content rotifers make up to 0.5%, cladocerans about 35% and copepods about 7% (Tatrai et al. 1997, Adámek et al. 2003, Kloskowski 2011). Such variability depends on many abiotic and biotic factors in ecosystems of lakes and ponds. The most significant factors forming community structure of zooplankton in lakes and ponds ecosystems are seasonal dynamic, predation, competition and resource supply, which in turn depend on nutrient inflow or eutrophication. Thus, it reflects the two "bottom up" and "top down" mechanisms regulating zooplankton community structure in aquatic ecosystems. Classically, the "bottom up" mechanism assumes that a positive correlation is observed between biomasses on all trophic levels, which is limited by nutrients, but the "top down" mechanism gives the opposite effect (the more piscivorous fish, the fewer planktivorous fish, the more zooplankton, the fewer algae, the more available nutrients) (Karabin 1985, Sommer et al. 1986, Gliwicz, Pijanowska 1989, Kitchell, Carpenter 1993, Soranno et al. 1993, Yoshida et al. 2003). An important factor that should also be taken into account to understand these regulatory mechanisms in lakes and ponds is the size–efficiency hypothesis. According to the classical size–efficiency hypothesis, large-sized cladocerans have higher feeding competitiveness than smaller species, but under the impact of predators the balance can shift in favour of small-sized cladocerans and rotifers (Hall et al. 1976, Lampert, Sommer 2007). Many studies show that the size of zooplankton in lakes is closely related to the abundance and competition of planktivorous fish or invertebrate predators (Dodson 1974, Carpenter et al. 1985, Soranno et al. 1993, Declerck 1997, Napiórkowska-Krzebietke 2017).

Different densities of fish in lakes show that the amount of large-sized *Daphnia* decreases as the density of fish increases. Thus, competition is reduced, but the abundance of small-sized cladocerans *Bosmina*, *Chydorus* and small cyclopoids (*Mesocyclops*, *Thermocyclops*) increases; also the abundance of predatory rotifer *Asplanchna priodonta* rises. The impact of fish predation on the rotifers community structure can be both direct and indirect. Indirect predation can appear through increasing abundance and productivity of rotifers, and mainly it is related to key rotifer species (*Keratella, Brachionus*) with a wide range of feeding that competes with cladocerans. Rotifers also suffer from predation of copepods. It also depends on the state of lakes: in shallow clear macrophyte lakes with low chlorophyll concentration and low fish density, but with high density of macroinvertebrates zooplankton community structure is dominated by large microphagous cladocerans *Daphnia* and phytophilous *Simocephalus vetulus* and *Scapholeberis mucronata*, as well as by predator *Polyphemus pediculus*, but in ponds with turbid-water state and opposite environmental conditions dominants are rotifers *Asplancha*, *Polyarthra*, *Brachionus* and *Keratella,* and cyclopoid copepods (Williamson 1983, Биотические взаимоотношения ... 1993, Cottenie et al. 2001, Kurbatova, Lapteva 2008, Napiórkowska-Krzebietke 2017).

In fisheries, including those in Latvia, ponds are widely used in aquaculture for fish and crustaceans cultivation. The amount of ponds in Latvian fish farms tends to increase. However, their number is not large; from 2007 to 2018 the number has increased from 311 to 766 ponds. The total area of fish farms does not exceed 6000 ha (Akvakultūras produkcijas ražošana, Zemkopības ministrija, 2020), and they are mainly privately-owned farm ponds. Consequently, complex researches or state environmental monitoring is not performed there. This study aim was to investigate the community structure of zooplankton, as zooplankton makes up one of the basic trophic links of aquatic systems, its structure and dynamics in ponds reflect the fish farming practices and water quality.

MATERIAL AND METHODS

This study was carried out in the fish farm ponds of Nagļi. The fish farm Nagļi located in the South-Eastern part of the Lubāna plain in the lowland of Eastern Latvia (Fig. 1). Fish farm Nagļi has been operating since 1965, and it is the largest fish farm in Latvia with a total area of about 2000 ha and a full fish farming cycle. The fish farm together with Lubāna Lake forms specially protected natural area the nature reserve "Lubānas mitrājs", simultaneously, it is *Natura 2000* and *Ramsar* territory. Farm fish ponds are in flat floodplain peatlands. The studied ponds belong to the group of the Nagļi-Ļodāni fish ponds. They are isolated, small, and very shallow with water level that maintained by a flow from Nagļi Reservoir of the Malta River (Zīverts 1995, 1997). Ponds 1 – 6 are wintering ponds with a small area, the largest is around 0.50 ha and the smallest around 0.35 ha. Ponds' bed was covered by plants. During the study, 3-4-week-old juveniles of carp were grown in ponds, except for Pond 1. Pond 7 is about 0.80 ha and about 1.6 m deep (adult pike-perch and non-adult crucian carp were grown here).

The study was conducted in May and July 2018. Physico-chemical measurements of water were done using ©OTT Hydrolab water multiparameter probe, determining the following parameters: water temperature °C, conductivity µS cm^{-1}, dissolved oxygen mg l^{-1}, pH, oxidative reduction potential mV, and chlorophyll α µg l^{-1}. Water transparency was measured using the Secchi disc in Pond 7. Zooplankton samples were obtained using ©KC Denmark plankton net of 65 µm mesh size filtering 100 l of water and preserved immediately in 75% ethanol. In May, zooplankton samples were collected in seven ponds (Ponds 1 to 7). In Pond 1 (without fish and their juveniles) zooplankton samples were collected at two sites, in Pond 7 zooplankton samples were collected at three sites, in the other ponds at one site. In July, collection of zooplankton samples and measurements of water physico-chemical measurements were carried out in two ponds (the pond 1 and 7) at two sites. In July, due to the lowered water level in the other winter ponds, repeated research was not possible (Fig. 1).

The analysis of zooplankton samples was done using *ZEISS Primo Star* microscope (100-400 x magnification) equipped with *ZEIZS AxioCam ERc 5s* camera, a software and a micrometre. Zooplankton was identified and counted in six subsamples (1 ml) using gridded Sedgewick Rafter counting chambers. Zooplankton identification to species, genus, family or higher taxonomic level was done based on the following literature: Segers 1995, Smirnov 1996, Nogrady, Segers 2002, Radwan et al. 2004, Определитель зоопланктона и зообентоса...., 2010 and other. Nauplii, copepoda copepodites

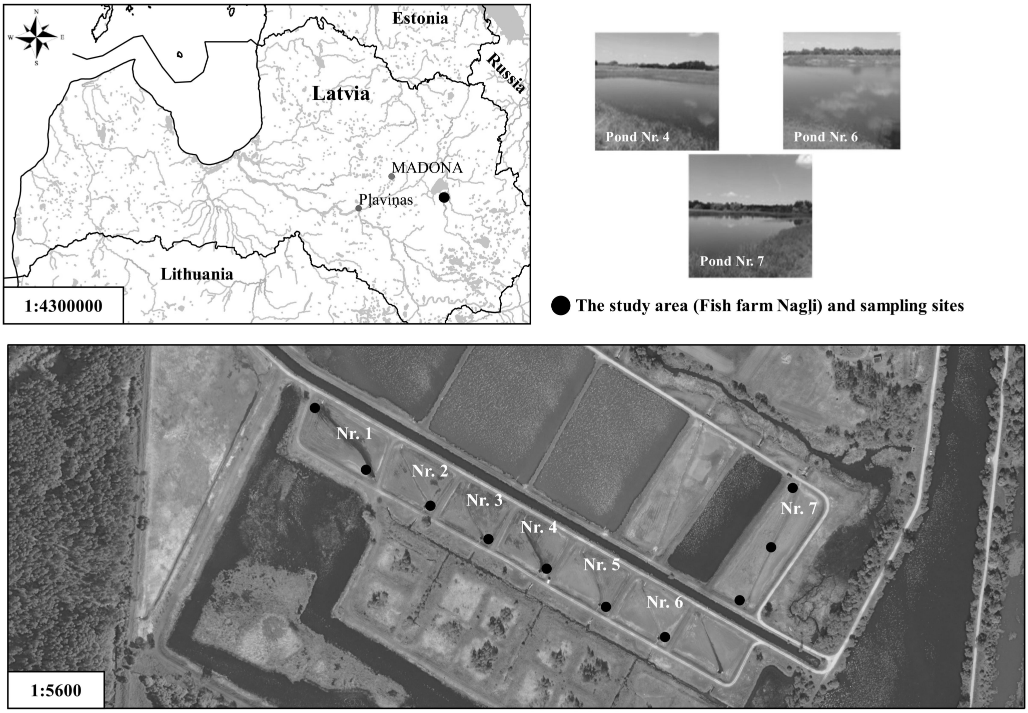

Fig. 1. The study area and sampling sites in the Fish farm Nagļi, 2018.

and adult copepods were enumerated separately. The body length of at least 20 individuals from each taxa was measured. The body length of zooplankton was converted to biomass (as wet weight) based on length-weight regressions (Мордухай-Болтовский 1954, Балушкина, Винберг 1979, 1979a, Ejsmont-Karabin 1998).

Abundance (ind. m^{-3}) and biomass of zooplankton (g m^{-3}), and Shannon-Wiener species diversity index (H') by abundance was analysed (Wetzel, Likens 2000, Plankton 10200. StandardMethods for the Examination... 2017, Krebs 1999). Spearmen's rank correlation analysis was used to reveal the interactions between the limnological parameters of ponds (water physico-chemical and biological). Data analysis was done using *IBM SPSS Statistics 20*.

RESULTS AND DISCUSSION

Water quality parameters

The water temperature was high enough and similar in all fish ponds and in both months of the study (in May, mean 23.3 °C ± SD - standard deviation 1.15, in July, mean 23.9 °C ± SD 1.15) (Fig. 2) and suitable to carp ponds (Boyd, Tucker 1998, Bhatnagar, Devi 2013). In May, the mean concentration of dissolved oxygen was 5.92 mg l^{-1}± SD 2.55. Lower concentration of dissolved oxygen was observed only in Pond 3 (mean 2.00 mg l^{-1}), which could be explained by the water exchange rate and the level (as was observed), or by more intense aquatic respiration process due to the cover of plants or by sediment oxygen demand (Dodds 2002, Baxa et al. 2020). In July, the mean concentration of dissolved oxygen was 6.97 mg l^{-1} ± SD 1.01. The dissolved oxygen was relatively high in both months and suitable for the development of fish, as evidenced by the relatively high oxidation-reduction potential (Boyd, McNevin 2015, Boyd, Tucker 1998) (Fig. 3, 4). The concentration of chlorophyll α was varied seasonally. In May, it was higher (mean 4.97 μg l^{-1} ± SD 2.35) and varied between the ponds. Higher concentrations were in Pond 6 (max 10.44 μg l^{-1}) and Pond 7 (max 7.21 μg l^{-1}), as also evidenced by the transparency of water 0.60 m. In July, the concentration of chlorophyll α was lower (mean only 2.03 μg l^{-1}) (Fig. 3, 4). Overall, these are relatively low figures. In fish ponds, where productivity is improved additionally, chlorophyll concentrations can range from 60 to 150 μg l^{-1} (Boyd, Tucker 1998). For example, in studies of phytoplankton communities and chlorophyll α in the ponds of the fish farm "Vileyka" in Belarus, the average chlorophyll α concentration was 80.6 μg l^{-1} (Adamovich, Zhukova 2014). In May,

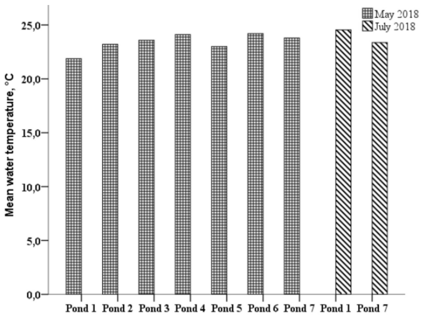

Fig. 2. Mean water temperature in the ponds.

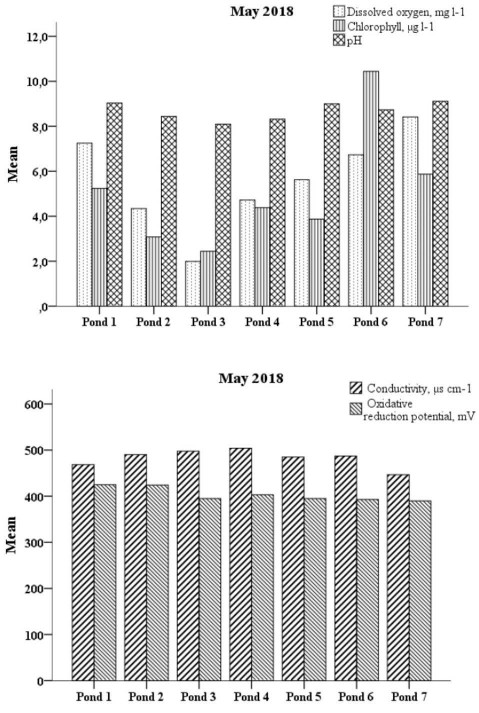

Fig. 3. Mean physico-chemical parameters in the ponds, May.

the mean conductivity was 476 µS cm^{-1} ± SD 22, in July, respectively 463 ± SD 25, without significant differences between the ponds and as our researches from the 2019 show, it depends on the inflowing waters of the Malta River (personal comment, unpublished). The water conductivity corresponds to hard waters and is suitable for fish ponds. The pH in May and July in ponds was optimal for fish ponds and mean changed from 8.7 ± SD 0.4 in May to 9.0 in July ± SD 0.1 (Fig. 3, 4) (Boyd, Tucker 1998).

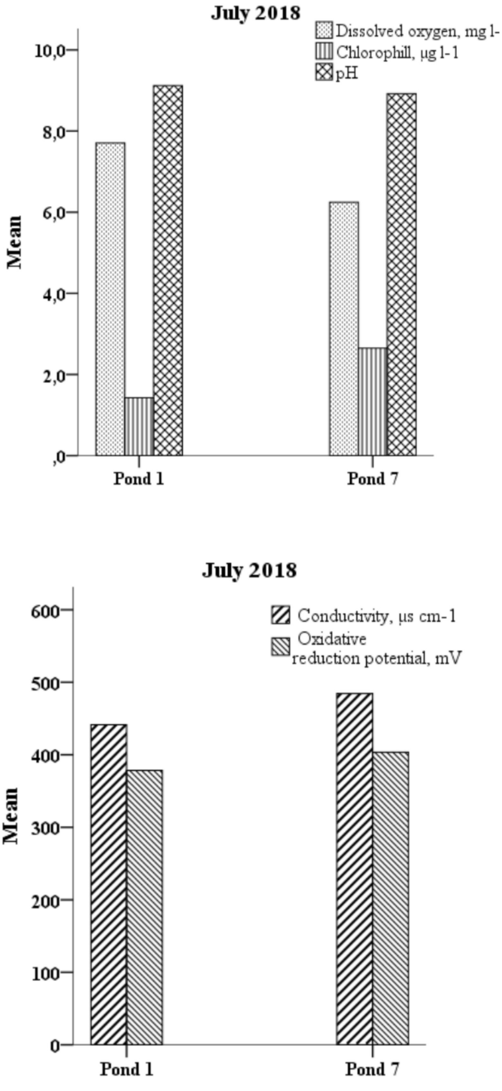

Fig. 4. Mean physico-chemical parameters in the ponds, July.

Zooplankton community structure

Although ponds are very similar (morphologically, with one water source, location), the community structure of zooplankton differs by taxonomic composition, by abundance and biomass. Comparatively, Pond 1 without adult fish or their juveniles can be characterized as crustaceans (Cladocera, Copepoda) pond with a relatively low total abundance, a low number of taxa and a mean Shannon-Wiener's species diversity index (mean H' 1.57), but with high biomass of cladocerans (Table 1, 2, Fig. 5, 6, 7). In overall, comparatively higher seasonal variability of cladocerans taxa was observed at this pond. In May, community dominants were the different sizes fine filtratory and macrophyte-associated taxa of cladocerans as *Bosmina longirostris*, *Diaphanosoma*

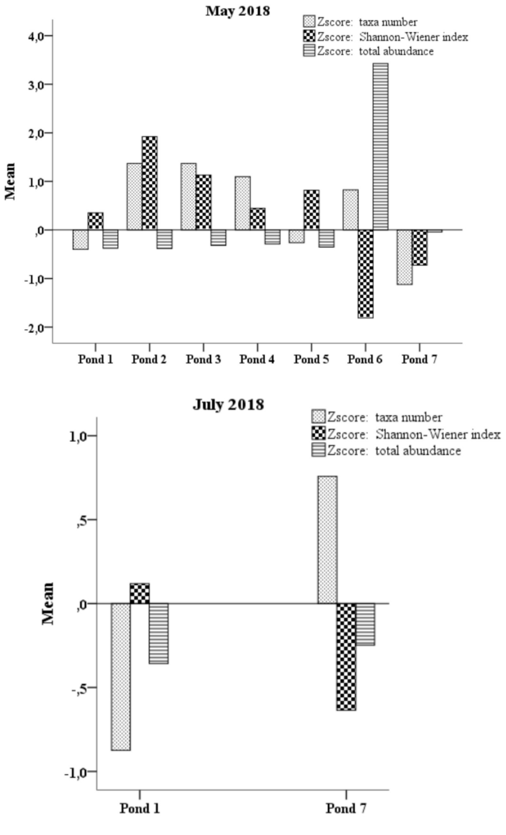

Fig. 5. Mean (Zscore) of zooplankton taxa number, Shannon-Wiener index and total abundance in the ponds.

Table 1.Zooplankton abundance and biomass of the ponds, May

	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Pond 7
Abundance of rotifers, ind. m^{-3}	42250	93167	184700	431833	266834	10978800	1174556
Biomass of rotifers, g m^{-3}	0.02	0.04	0.06	0.11	0.09	1.99	0.97
Abundance of cladocerans, ind. m^{-3}	75833	13500	13400	1833	500	22800	5722
Biomass of cladocerans, g m^{-3}	3.21	0.60	1.42	0.10	0.01	0.30	0.04
Abundance of copepods, ind. m^{-3}	112333	107333	195967	43333	32833	43600	4278
Biomass of copepods, g m^{-3}	0.73	1.33	1.47	0.44	0.39	0.45	0.03
Total abundance, ind. m^{-3}	230417	214000	394067	477000	300167	11045200	1184556
Total biomass, g m^{-3}	3.96	1.97	2.95	0.65	0.50	2.74	1.04

Table 2. Zooplankton abundance and biomass of the ponds, July

	Pond 1	Pond 7
Abundance of rotifers, ind. m^{-3}	29000	587584
Biomass of rotifers, g m^{-3}	0.003	0.39
Abundance of cladocerans, ind. m^{-3}	222500	1000
Biomass of cladocerans, g m^{-3}	8.07	0.01
Abundance of copepods, ind. m^{-3}	223750	7125
Biomass of copepods, g m^{-3}	12.15	0.35
Total abundance, ind. m^{-3}	475250	595709
Total biomass, g m^{-3}	20.22	0.76

brachyurum, *Chydorus* sp. and *Ceriodaphnia* sp., In July, the main dominants were *Ceriodaphnia* sp., *Chydorus* sp., *Pleuroxus* sp., as well as *Simocephalus vetulus, Acroperus* sp. and by biomass also *Scapholeberis mucronata*. The presence of the omnivorous predator cladoceran *Polyphemus pediculus* indicates that there are no other large predators in the pond. Abundance and biomass of rotifers are the lowest compared to other ponds in both May and July. Accordingly, due to the very low water level, the main dominants of rotifers were microphagous (feed on bacteria associated with detritus) *Conochilus* sp. and Bdeloidea, followed by microphagous (feed on algae and bacteria) Lecanidae and *Keratella cochlearis*. In July, the dominant one was *Lecane closterocerca*. The dominance of such loricate taxa as *Lecane closterocerca* can be explained by the predominance of cladocerans in lakes and ponds (Yoshida et al. 2003, Brysiewicz et al. 2017).

Ponds 2, 3, 4 and 5 with fish juveniles were more similar by the structure of the zooplankton community because the diversity and abundance of cladocerans decreased as the proportion of copepods and rotifers increased. However, there were differences in community structure among ponds 2, 3 and 4, 5 (Fig. 5, 6, Table 1). Copepods were characteristic for ponds 2 and 3 dominated by their nauplii and adult specimens, but in ponds 4 and 5 the proportion of rotifers increased. In these ponds a higher diversity of rotifers taxa was detected. Rotifers community is characterized by a relatively low total abundance and biomass, therefore the Shannon-Wiener species diversity index was higher. Rotifers macrophagous (feed on algae) become dominants in these ponds, in ponds 3, 4 *Polyarthra* sp. and Pond 5 *Synchaeta* sp. respectively.

Pond 6 is very distinct, mainly composed by rotifers, with higher abundance between ponds, dominated by *Keratella cochlearis*, thus reducing the Shannon-Wiener species diversity index. Crustaceans also were slightly increased by small-sized cladocerans *Chydorus* sp. and *Bosmina longirostris* abundance (Fig. 5, 6, Table 1). Pond 7 is the largest among all studied ponds, and the water level is continuously maintained in it because adult of pike-perch and non-adult crucian carp were grown here (Fig. 5, 6, 7, Table 1, 2). This pond can also be characterized as a rotifers pond, but unlike Pond 6, in May, in Pond 7 dominants by abundance was *Filinia longiseta, Keratella cochlearis, Synchaeta* sp., *Brachionus* and *Asplanchna priodonta,* the last one also was a considerable part of the total zooplankton biomass. Cladocerans were represented by *Bosmina longirostris,* copepods mostly by copepodites and nauplii. But in July, rotifers were dominated by *Synchaeta* sp., *Polyarthra* sp., as well as a large amount of *Anuraeopsis fissa*, *Filinia longiseta,* Bdeloidea, by biomass also *Asplanchna priodonta* were observed. Cladocerans were represented by *Chydorus* sp., but copepods - by adult specimens.

The differences in zooplankton community structure in the ponds can be explained both by the presence or absence of fish or fish juveniles and by crustaceans competition or predation, and the effect of the seasonal changes on the structure together with a nutritional food base (algae, bacteria) are also significant. Fish juveniles are zooplanktivorous and the zooplankton's consumption of fish juveniles (0+ carp, 2-5 cm) consists mainly of small cladocerans and copepods, as well as rotifers (Kloskowski 2011,

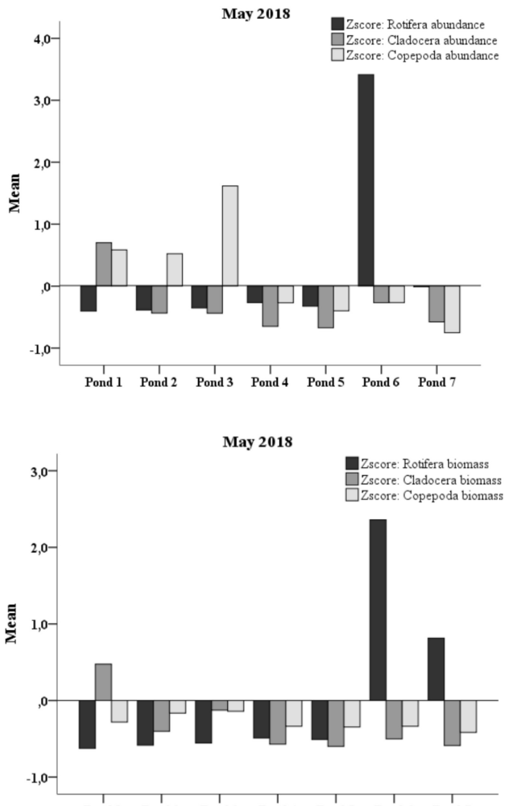

Fig. 6. Mean (Zscore) of zooplankton (rotifers, cladocerans, copepods) abundance and biomass in the ponds, May.

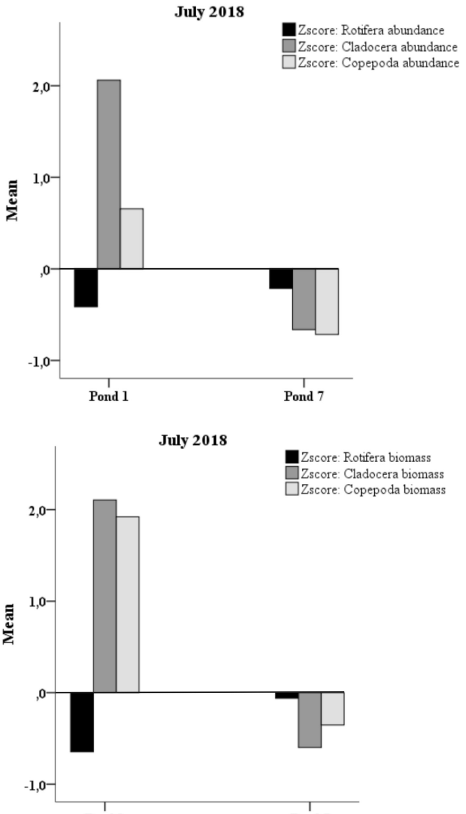

Fig. 7. Mean (Zscore) of zooplankton (rotifers, cladocerans, copepods) abundance and biomass in the ponds, July.

Nunn et al. 2012). Significant and negative correlation is maintained between the biomass of cladocerans, copepods and the biomass of rotifers (r=-0.68, p<0.007, r=-0.67, p<0.008 respectively), which suggest the impact of major competitors or predators (Cladocera, Copepoda) on rotifers in the studied ponds (Ponds 1 - 5). The more abundant microphagous rotifers *Keratella cochlearis*, *Filina longiseta*, *Anuraeopsis fissa*, *Bosmina longirostris*, *Chydorus* sp, also copepods and predator rotifer *Asplanchna priodonta* can suggest the seasonality, fish predation and “bottom up” control in the ponds, also evidenced by the positive correlation between chlorophyll α concentration and rotifers biomass (Spearman rank correlation, r=0.55, p<0.035). Shannon-Wiener species diversity index was higher in ponds 2, 3, 4, and 5 than in ponds 6 and 7. Such differences in the species diversity index may also indicate a predator effect in the ponds. Similar studies have found that in fish ponds dominated by rotifers with a high “top down” effect the zooplankton community species diversity decreases (Brysiewicz et al. 2017). The effect intensity of fish on the zooplankton community (composition and biomass) also could depend on the different density of fish or fish juveniles in the ponds (Lemmens et al. 2018). In pond and lake studies, there is a similar pattern in zooplankton community structure, the presence of rotifers (mainly *Keratella, Brachionus* and *Polyarthra, Synchaeta*) and small copepods (stages of nauplii and copepodites and adults copepods by small *Thermocyclops* sp.) and cladocerans *Bosmina longirostris, Chydorus* sp., as well as a tending upward rotifer predator *Asplanchna priodonta*, which suggests the impact of fish (Hall et al 1976, Carpenter et al. 1985, Cottenie et al. 2001, Биотические взаимоотношения ... 1993, Obertegger et al. 2011, Napiórkowska-Krzebietke 2017, Adámek et al. 2003, Gruberts, Paidere 2014, Lemmens et al. 2018). Such structure of the zooplankton community is opposite to Pond 1 without fish, where crustaceans dominated by cladocerans and *Polyphemus pediculus* occupied the role of predator and made higher crustaceans biomass.

CONCLUSIONS

Overall, ponds correspond to shallow eutrophic waters either with turbid water state (Ponds 6 and 7), as evidenced by the high abundance of rotifers, chlorophyll α concentrations and Secchi depth, either with clearer water state, which is characteristic for Pond 1 without fish. The species associated with macrophytes *Pleuroxus* sp., *Simocephalus vetulus* and *Scapholeberis mucronata* and the species that occur in clear waters *Polyphemus pediculus* are typical for this pond. In the presence of fish juveniles or fish the community structure of zooplankton both by biomass and abundance is characterised as copepods/small-sized cladocerans and rotifers or only rotifers ponds. Negative relationships between crustaceans and rotifers also indicate the interspecies competition and predatory. The presence of specialized species Synchaetidae, rotifers biomass /chlorophyll α positive correlation, the presence of microphagous (feed on bacteria, unicellular algae) *Filinia, Brachionus, Anuraeopsis fissa, Keratella*) also reflects the impact of seasonality and “bottom up” control on the community structure of zooplankton.

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