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IMPACT OF THE FISH CAGE AQUACULTURE ON THE ZOOPLANKTON COMMUNITY IN „KARDZHALI“ DAM LAKE, BULGARIA

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Abstract

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Based on complex water body investigations including also studies of zooplankton community the effect of cage fish breeding on zooplankton cenotic indicies of Shanon, Pielu and Simpson in „Kardzhali“ Dam Lake was analyzed. The spatial horizontal distribution of zooplankton biomass and the indicies of species diversity distinguished the zone in proximity of cage facilities as most antropogenically loaded, while the remote aquatic regions showed relatively high species diversity and stability values. Additionally the ratio Cladocera/Copepoda by biomass was calculated and the vertical zooplankton gradient distribution presented.

Key words: zooplankton, dam, trophic status

Introduction

The zooplankton is very important basic element of ecological food chains in limnetic ecosystems. Depending on the environmental conditions different zooplankton taxa and concentrations are developed. The larger part of zooplankton are filtrators, feeding predominantly on phytoplankton and seston but there are also considerable groups of predators, consumers of second and third rank feeding on filtrator species. Thus the total zooplankton abundance depends on species composition and development dynamics. In number of cases it is important to know which factor is zooplankton determining at a time – the trophic resources, temperature, fish press or another factor. This might determine which kind of influence is the most effective for zooplankton quality and quantity with the aim to improve the water quality of water bodies.

Besides as a basic link in the trophic chain and a powerful factor influencing water quality due to specific requirements of its different species the zooplankton is also an indicator for water purity. Therefore the description of its species composition and qualitative dynamics composes the basis of trophic characteristics of considered aquatic ecosystems. In the recent investigations the authors considered the reactions of planktonic communities and of ecosystems as a whole as a result of natural and anthropogenic factors. Such an approach provides a better understanding of mechanisms determining species structure and abundance dynamics of zooplankton. Considering the reservoir trophy Naidenov (1984) showed an increase of zooplankton species composition and diversity from oligo to mesotrophic state and especially to hypertrophy. There are tendencies of changes in indicator species, abundance and biomass described when the trophy increases. The zooplankton organisms are in the basis of many of developed saprobic systems for water analyses (Karabin, 1985; Szlauer, 1999). Differently from chemical measurements of organic and oxygen concentrations in waters the saprobic methodology delivers more reliable and

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lasting estimation by eliminating the short-term fluctuations in chemical characteristics. The classic saprobic system was developed by Pantle and Buck (1955) and substantially improved later by Sladecek (1973), whose method accounted for species share in the zooplankton community. In Bulgaria Naidenov (1981) and Naidenov, Saiz, (1987) applied the saprobic index of Rothschtein (1962) too.

There are 109 zooplankton species found in Bulgarian dam lakes (Naidenov, 1984). The same author reported about 12 species in „Ivailovgard" and 60 species in „Batak" dam lakes. The steps of „Arda" cascade dam seemed to be the poorest in zooplankton. First Traykov (2005) studied the zooplankton of „Kardzhali" Dam Lake.

The goal of this study is to discover the role of fish cage breeding on zooplankton community in the „Kardzhali" Dam.

Materials and Methods

The samples were taken with quantitative fractional net of Juday type (silk gaze №12/49) with 20 cm opening diameter by means of vertical hauling from several depth intervals (surface – 10 m, 10–20 m, 20–30 m and 30–40 m). We preserved the samples in 4% formalin final concentration (Figure 1).

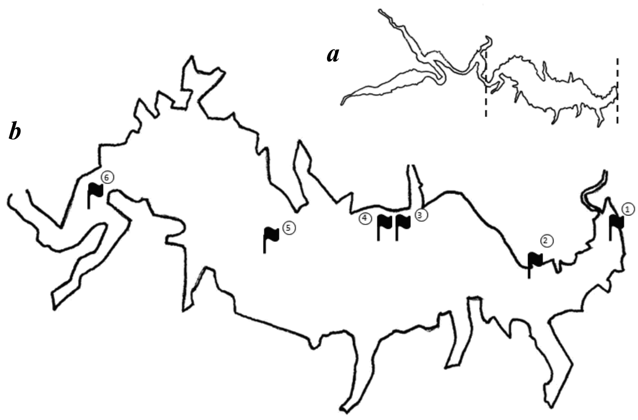


Fig. 1. Schematic map of „Kardzhali" dam
***a* – general scheme,**
***b* – location of sampling stations in the reservoir area**

The zooplankton samples were qualitatively and quantitatively analyzed. The numerical abundance was determined after Dimov (1959), and biomass after Prikryl (1980).

In order to achieve higher precision the zooplankton biomass was calculated by means of standard individual weights for each species and development stage according to Morduhai – Boltovskoi (1954).

Results and Discussion

Species composition

The taxonomic structure of zooplankton community in „Kardzhali" Dam included 13 Rotatoria 11 Cladocera and 5 Copepoda species. The nauplii and copepodid development stages of Cladocera and Copepoda were encountered during almost the whole period of study (Tables 1 and 2). The zooplankton community was distinguished by considerable species diversity and included characteristic for Bulgarian freshwaters taxonomic groups (Kozuharov et al., 2013; Kozuharov et al., 2007; Tisheva and Kozuharov, 2013; Naydenov, 1993).

The most frequently encountered Cladocerian species were *Daphnia. lot. longispina, Daphnia. lot. pulex,* and *Ceriodaphnia pulchella*. From Rotifers *Asplanchna sieboldi, Kellicottialon gispina and Fillinia longiseta* were available throughout the whole year. *Eudiaptomus gracillis* and *Cyclops vicinus* from Copepoda were encountered during the whole season while *Eurytemora velox* and *Cyclops strenuous* were absent during the autumn months. As a whole the zooplankton community of the reservoir is of crustacean type. The dominance of Cladocera over Copepoda in ratio 3:1 indicates high concentration of their trophic basis – the phytoplankton.

The obtained results confirmed the low species diversity of „Kardzhali" Dam found by Traykov et al. (2003, 2005) in comparison to other reservoirs in Bulgaria, where the species number amounted to 115 (Kozuharov et al., 2007; Kozuharov et al., 2013; Tisheva and Kozuharov, 2013). Despite that it is the highest in comparison to other reservoirs of the cascade due to the short hydraulic residence time (Naydenov, 1984).

Numbers of zooplankton in „Kardzhali" Dam

The number of individuals belonging to Cladocera was the highest during the investigation period, followed by Copepoda and Rotatoria (Figure 2). The percentage share distribution of the three groups showed values close to those reported by Naidenov (1984a, b) and Kozuharov (2013) relationships in other Bulgarian waters, according to which Cladocera took up to 62% from total number. Similar values were found by Traykov (2003) for the limnetic part of „Kardzhali" Dam. He reported higher values only for the transitional zone due to strong development of *Bosminidae* family. In our study there were no differences in the community structure between years 2009 and 2011 and Cladocera took 68% from total abundance during the first year at the expense of lower numbers of Copepoda order.

Table 1

Taxonomic composition of zooplankton community in „Kardzhali“ Dam during year 2009

Taxons	Date				
Rotatoria	V.2009	VII.2009	IX.2009	XI.2009	IV.2010
Trychocerca pusilla (Jennings, 1903)	–	+	+	–	–
Brachionus calyciflorus (Pallas, 1766)	–	+	+	–	+
Keratella cochlearis (Gosse, 1851)	+	+	+	–	+
Keratella quadrata (Müller, 1786)	–	–	+	+	–
Kellicottia longispina (Kellikot, 1879)	+	+	+	+	+
Asplanchna sieboldi (Leydig, 1854)	+	+	+	+	+
Asplanchna sp.	–	+	–	–	+
Fillinia longiseta (Ehrenberg, 1834)	+	+	+	+	+
Polyarthra dolichoptera (Idelson, 1925)	+	–	–	+	+
Polyarthra vulgaris (Carlin, 1943)	+	+	+	–	+
Cladocera					
fam. Sididae					
Diaphanosoma brachiurum (Lieven, 1848)	+	+	+	–	–
fam. Daphnidae					
Daphnia s. lot. pulex (Leydig, 1862)	+	+	+	+	+
Daphnia cuculata (Sars, 1862)	+	–	+	+	+
Daphnia s. lot. longispina (Müller, 1785)	+	+	+	+	+
Daphnia sp. juv.	+	+	+	–	+
Ceriodaphnia pulchella (Sars, 1862)	+	+	+	+	–
Leptodora kindti (Focke, 1844)	+	+	–	–	+
fam. Bosminidae					
Bosmina s. lot. longirostris (Müller, 1785)	+	+	+	+	+
Bosmina coregonii (Baird, 1857)	+	–	+	+	–
fam. Chydoridae					
Leydigia s.str. leydigii (Leydig, 186)	+	+	–	–	+
Chydorus sphaericus (Müller, 1785)	–	+	+	–	+
Copepoda					
ord. Cyclopoida					
Cyclops vicinus (Uljanin, 1875)	+	+	+	+	+
Acanthocyclops robustus (Sars, 1863)	+	+	+	–	–
Copepodites Cyclopoida	+	+	+	+	+
ord. Calanoida					
Eudiaptomus gracillis (Sars, 1863)	+	+	+	+	+
Eurytemora velox (Lill, 1853)	+	+	+	–	+
Nauplii	+	+	+	–	+

Legend: (+) Found in the dam during the visit. (–) Not found in the dam during the visit

Zooplankton quantity characteristics were highly variable during the investigated period. There are variations in zooplankton numbers between the seasons as well as between the sampling stations. The annual average values of single taxa forming the zooplankton community are shown on Figure 2.

In the first investigation period only one peak of zooplankton number occurred during the spring months. During year 2009 the lowest values of 5800 individuals.m^{-3} for sampling station No 2 and highest of 295000 individuals.m^{-3} for sampling station No 3 in May was reported. During the summer months a minimum of zoo-

Table 2

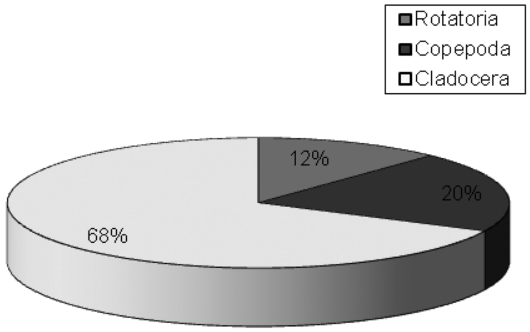
Taxonomic composition of zooplankton community in „Kardzhali“ Dam during year 2011

Taxons	Date			
Rotatoria	IV. 2011	VI. 2011	VIII. 2011	X. 2011
Keratella cochlearis (Gosse, 1851)	–	+	–	+
Keratella quadrata (Müller, 1786)	+	+	–	+
Brachionus angularis (Gosse, 1851)	+	+	+	+
Kellicottia longispina (Kellikot, 1879)	+	–	+	+
Asplanchna sieboldi (Leydig, 1854)	+	+	+	+
Asplanchna priodonta (Grosse, 1850)	–	+	+	+
Filinia major (Colditz, 1914)	+	+	–	–
Filinia terminalis (Plate, 1886)	+	+	–	–
Fillinia longiseta (Ehrenberg, 1834)	–	+	+	–
Polyarthra vulgaris (Carlin, 1943)	+	+	+	+
Cladocera				
fam. Sididae				
Diaphanosoma brachiurum (Lieven, 1848)	+	+	+	–
fam. Daphnidae				
Daphnia s. lot. pulex (Leydig, 1862)	+	–	–	–
Daphnia s. lot. longispina (Müller, 1785)	+	+	+	+
Daphnia p. curvirostris (Eylman, 1886)	+	+	+	+
Daphnia sp. juv.	+	+	+	+
fam. Leptodoridae				
Leptodora kindti (Focke, 1844)	+	–	–	–
fam. Bosminidae				
Bosmina s. lot. longirostris (Müller, 1785)	+	+	–	+
Bosmina coregonii (Baird, 1857)	+	–	+	–
fam. Chydoridae				
Chydorus sphaericus (Müller, 1785)	–	+	+	–
Copepoda				
ord. Cyclopoida				
Cyclops vicinus (Uljanin, 1875)	+	+	+	–
Acanthocyclops vernalis (Fischer, 1853)	+	+	+	+
Acanthocyclops robustus (Sars, 1863)	+	+	–	+
ord. Calanoida				
Eudiaptomus gracillis (Sars, 1863)	+	+	+	+
Copepodites	+	+	+	+
Nauplii	+	+	+	+

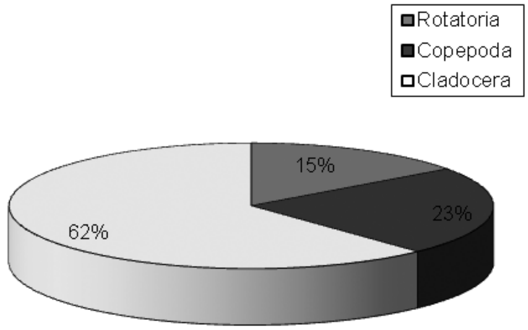
Legend: (+) Found in the dam during the visit. (–) Not found in the dam during the visit

plankton abundance with values of 21 300 for station No 6 and 20 700 individuals.m^{-3} for station No 1 were reported. A small increase of zooplankton number close to fish farming facilities without reaching statistically significant differences (ANOVA, $P > 0.05$) was registered. This tendency was sustained during the autumn months of 2009. There is no second peak in development observed in previous investigations of the reservoir (Traykov, 2003), characteristic for big part of Bulgarian reservoirs (Naidenov, 1984b, Kozuharov et al., 2007; 2013).

The reare several times high erabundance values on all stations during 2011 than in 2009, varying from 28 200 at station 2 till 647 800 individuals.m^{-3} at station No 4. Again the highest values were found during the spring maximum. In 2011 it was shifted to the later spring months differing considerably from the reported by Traykov et al. (2011) abundance maximum in March during 2001–2002 periods. To great extend this is result from the low month av-



a



b

Fig. 2. Percentage distribution of main taxonomic zooplankton groups in waters of „Kardzhali“ Dam for period
***a* – May 2009– April 2010;**
***b* – April 2011– March 2012**

erage temperatures during the early spring months (March and April) of year 2011. There corded values at stations No 3 and No 4 were significantly higher in comparison to results obtained at station No 5 – 235 200 and station No 6 – 292 800 individuals.m^{-3} (ANOVA, $P < 0.05$). The lowest number during the vegetation period (140 200 individuals.m^{-3}) was recorded in July nut in August a new weaker expressed peak in number was observed and the values remained unchanged during November (Figures 3 and 4).

The taxa of zooplankton community showed different dependence on seasons in the investigation period.

Rotatoria

Kellicottia longispina and genus *Asplanchna*s howed the highest numbers. In year 2009 the Rotatoria abundance varied in close range – between 2100 and 31 800 Ind. m^{-3} with relative stable values between the sampling stations. The highest abundance was observed during the spring season. In 2011 the annual average number of Rotatoria was in the range 6300–118 600 Ind. m^{-3} and was decreasing towards the dam (station No 6). Station No 4 was an exception, where the maximum value of 131 600 Ind. m^{-3} was recorded (Figure 3).

Cladocera

The annual average number of stations was relatively stable (Figure 3). The highest values were recorded on

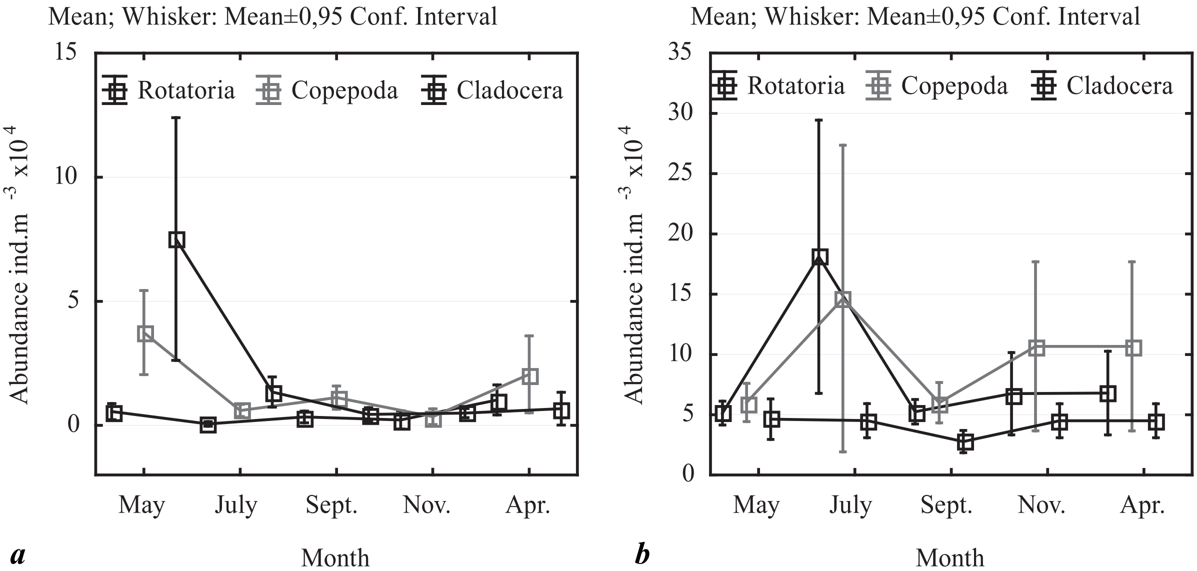


Fig. 3. Changes in numbers of main zooplankton taxonomic groups in „Kardzhali“ Dam for investigation period (*a* – 2009; *b* – 2011)

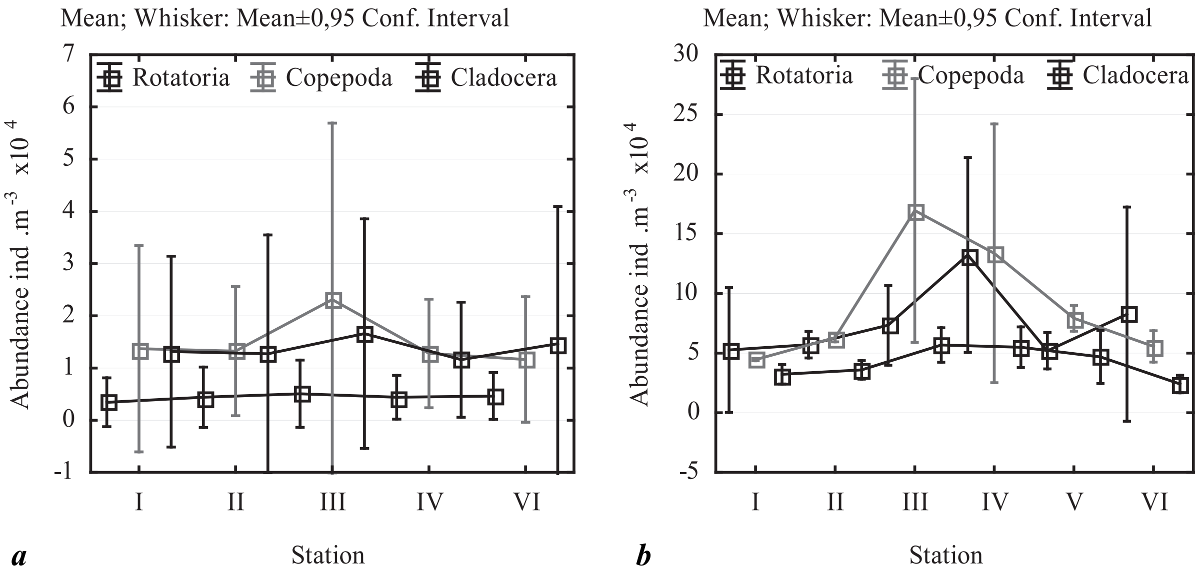


Fig. 4. Changes in numbers of main taxonomic groups of zooplankton between stations in „Kardzhali“ Dam for years *a* – 2009 and *b* – 2011

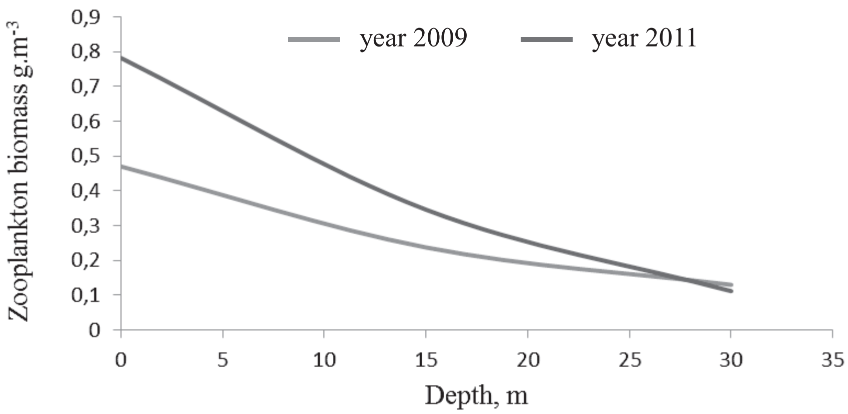


Fig. 5. Average values of zooplankton biomass presenting its vertical depth distribution in „Kardzhali“ Dam

stations No 3 and No 4 (67 300 Ind. m^{-3}) while the lowest occurred on station No 6 (16 100 Ind. m^{-3}). The seasonal dynamics was clearly expressed and followed the already described relationship (Figure 7).

The Daphnia species were encountered during the whole year with *Daphnia s. lot. longispina* presented by highest number. The abundance of *Bosminidae* family was composed mainly by *Bosmina longirostris* occurring during the whole investigation period. Traykov et al. (2011) found that this species played a basic role in the transitional zone of the dam because the family showed the strongest longitudinal gradient for its annual average number. *Bosminacoregonii* was available in the surface layer during the spring and autumn months, while during the summer its numbers decreased and it was found maily in the hypolimnion. The coexistence of both species is a result from clearly expressed longitudinal gradients of physic-chemical and biological factors in „Kardzhali“dam (Traykov et al., 2011). Family *Sididae* was found mainly in the late spring months of the year. Family *Chydoridae* showed the lowest number. They were present only in August and September of year 2011.

Copepoda

The subclass Copepoda was presented with two orders Cyclopoida and Calanoida. This taxon is characterized with highest number in this investigation. Its number increased towards station No6 (57 700 Ind.m^{-3}) and station No3 (278 800 Ind.m^{-3}) and decreased towards the dam of the reservoir. After Karabin (1985) the changes of abundance of mentioned species reflected the trophic gradient, which is increasing towards the cage facilities in the dam.

The reported values were completely in contrast with findings of other authors (Naidenov and Baev, 1987; Kozuharov et al., 2013; Traykov et al., 2011; Traykov, 2005). Traykov (2003) found a stable decrease of numbers from the zone with stronger flow towards the reservoir dam. These differences are due to specifics of selected sampling stations. The low values found in the free aquatory and in comparison with stations No 3 and No 4 and tendencies found by Traykov (2003), were characteristic for local influence of cage farming facilities, which could not affect the whole water area of „Kardzhali“ Dam. The dominance of order *Cyclopoida* over order *Calanoida* is an indicator for the eutrophic character of the dam.

Horizontal and vertical changes of zooplankton biomass

The zooplankton biomass values did not follow completely the changes in numbers, mainly because of considerable differences in individual weights of zooplankton species. In the surface layer the highest zooplankton biomass values were registered at stations No 3 and No 4 and for year 2009 they were in the range 0.72 g.m^{-3} and 0.76 g.m^{-3} and for 2011 0.964 g.m^{-3} and 1.048 g.m^{-3}, while the lowest values were registered at stations No 1 and No 2 – 0.41 g.m^{-3} to 0.520 g.m^{-3} for the whole investigation period. The high zooplankton abundances in proximity of sturgeon cage farms are result of better trophic conditions for zooplankters, which is caused to great extent by the imported pelleted feed for sturgeon feeding.

In the free water area (station No 5) the zooplankton biomass is comparable with values registered at station No 6 – 0.785–0.842 g.m^{-3}, which is indicative for homogeneity of this region. There were lower values for zooplankton biomass in eutrophic layer in vicinity of reservoir dam – 0.520–0.582 g.m^{-3}. However, the measured high concentrations of Chl *a* (4.85 µg.l^{-1}) in the same zone suggested that the low zooplankton abundance is not due to the lack of food but rather is caused by the fish press exerted by the bleak (*Chalcalburnus chalcoides*, Güldenstädt).

The vertical distribution of zooplankton revealed a stable tendency to reduction with the increasing depth on all sampling stations (Figure 5). The main zooplankton quantity is concentrated in the 10 m surface layer bellow which a sharp decrease in number and biomass was registered and in depth of 20 m or 30 m only single individuals presented mainly by Cladoceran – *Chydorus sphaericus* occurred.

The recoreded epilimnion maximum is characteristic for the bigger part of waters in Bulgaria (Naydenov, 1983; Kozuharov et al., 1997, 2013; Traykov et al., 2011; Traykov, 2003). The dominance of Cladocera with increasing depth

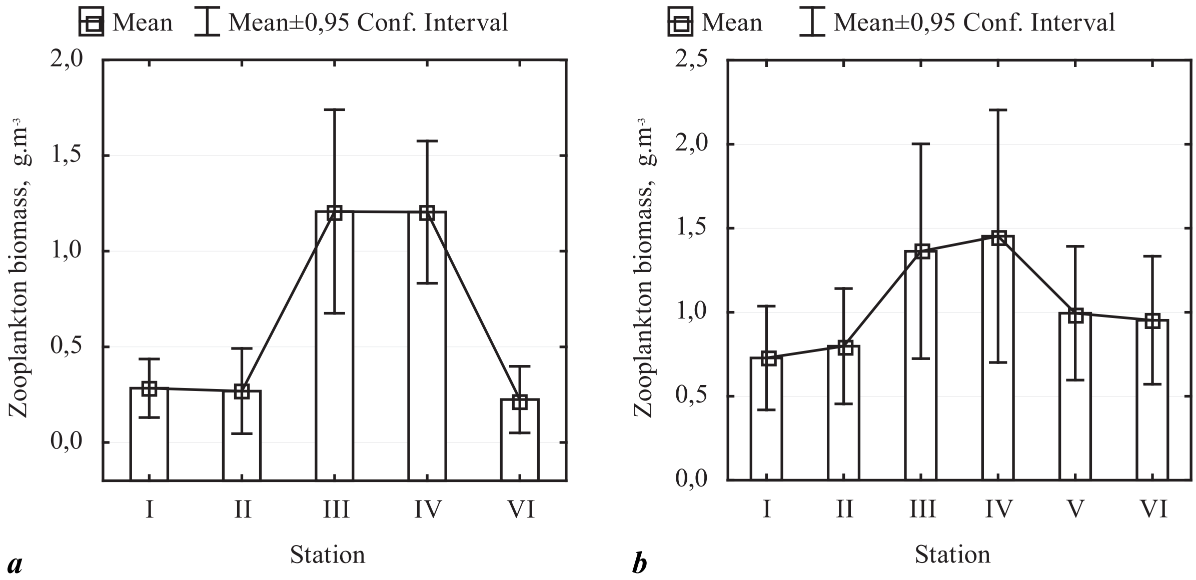


Fig. 6. Average values of zooplankton biomass distributed between sampling stations
***a* – 2009; *b* – 2011**

indicates the gradual reduction of zooplankton in the water column due to the depletion of foods and diminishing of light.

The light, temperature and oxygen gradients are decisive for zooplankton development. After the establishment of thermal stratification an anoxic layer is formed in the metalimnion (Traykov, 2005; Iliev and Hadjinikolova, 2013). This fact was confirmed by Ravera (1996), according to him the oxygen concentration is the main limiting factor for zooplankton distribution in the water column.

The zooplankton biomass showed considerable annual difference with average values varying in the range 0.22 g.m^{-3} – 0.48 g.m^{-3} in 2009 and 0.856 – 1.249 g.m^{-3} in 2011. The registered zooplankton increase in surface layer of station No 3 (1.223 g.m^{-3}) and station No 4 (1.249 g.m^{-3}) in 2011 influenced both the general depth profile for the mentioned sampling stations and the data for the whole water area of the dam (Figure 6).

In front of the reservoir dam and on station No 2 the biomass values were similar 0.864 – 0.856 g.m^{-3}. The same tendency is observed in the limnetic and semi transitional zone of the dam.

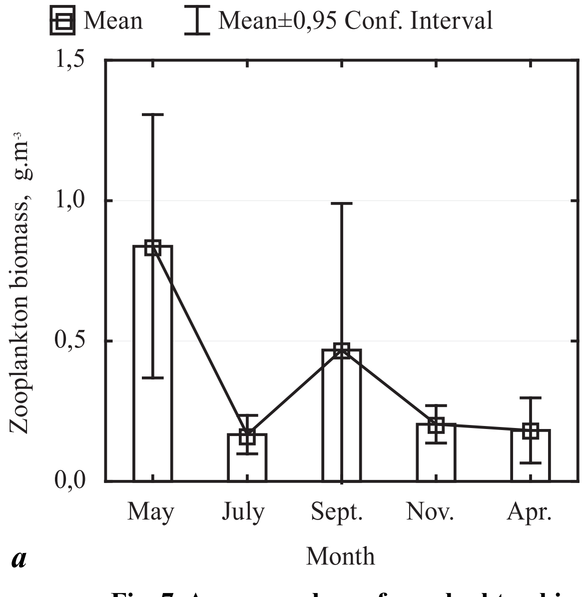
Seasonal dynamics of zooplankton communities

In seasonal aspect the pattern found by Naidenov (1993) and Lyudskanova (1967) was confirmed – a peak of zooplankton biomass in spring occurred which in our case reached a whole reservoir average value of 2.126 g.m^{-3}. In the summer months the zooplankton strongly decreased with July and August values of 0.478 g.m^{-3} and 0.496 g.m^{-3} correspondingly which is a fivefold decrease in comparison with the spring biomass. In November a new increase is observed reaching 1.069 g.m^{-3} (Figure 7).

Biocenotic zooplankton indices

The dynamics of species diversity indices during the period of study distinguished the free aquatic area and semi-transitional zone of the reservoir as at least impacted ones by the fish cage aquaculture. In these two regions we found maximal values of Shannon and Pielou indices calculated by biomass and minimal values of Simpson index (Figure 8).

From the dam and from the transitional reservoir zone towards the sturgeon farming facilities both indices for species diversity after Shannon and for evenness after Pielou decreased under the influence of anthropogenic impact, but the degree of dominance in the community after Simpson increased. The sampling stations No 3 and No 4 are the most strongly impacted by fish breeding for the whole period of investigation. The Shannon index in the mentioned zone was varying in the range 0.98 – 1.4, of Pielou between 0.4–0.69, and that of Simpson between 0.45–0.63. The zooplankton community demonstrated an especially low stability during July and August (Figure 8c, 8d), most probably due to more intensive fish feeding and increased water temperature. During the spring (Figure 8e) and later in the autumn the zooplankton structure showed the lowest difference from the remaining parts of the water body.



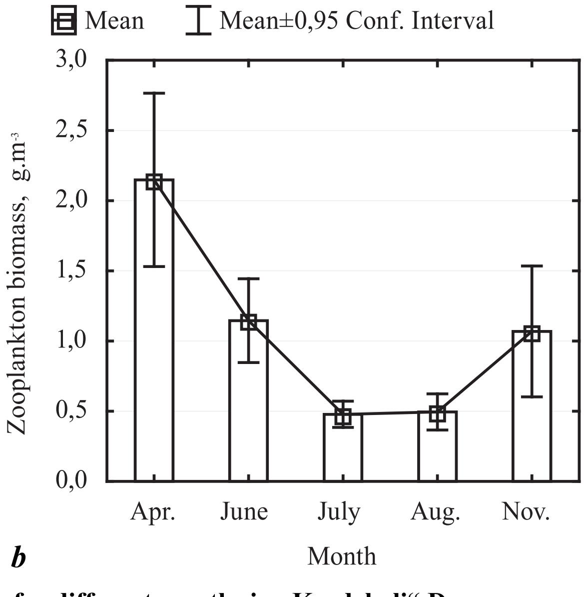


Fig. 7. Average values of zooplankton biomass for different months in „Kardzhali“ Dam
***a* – 2009; *b* – 2011**

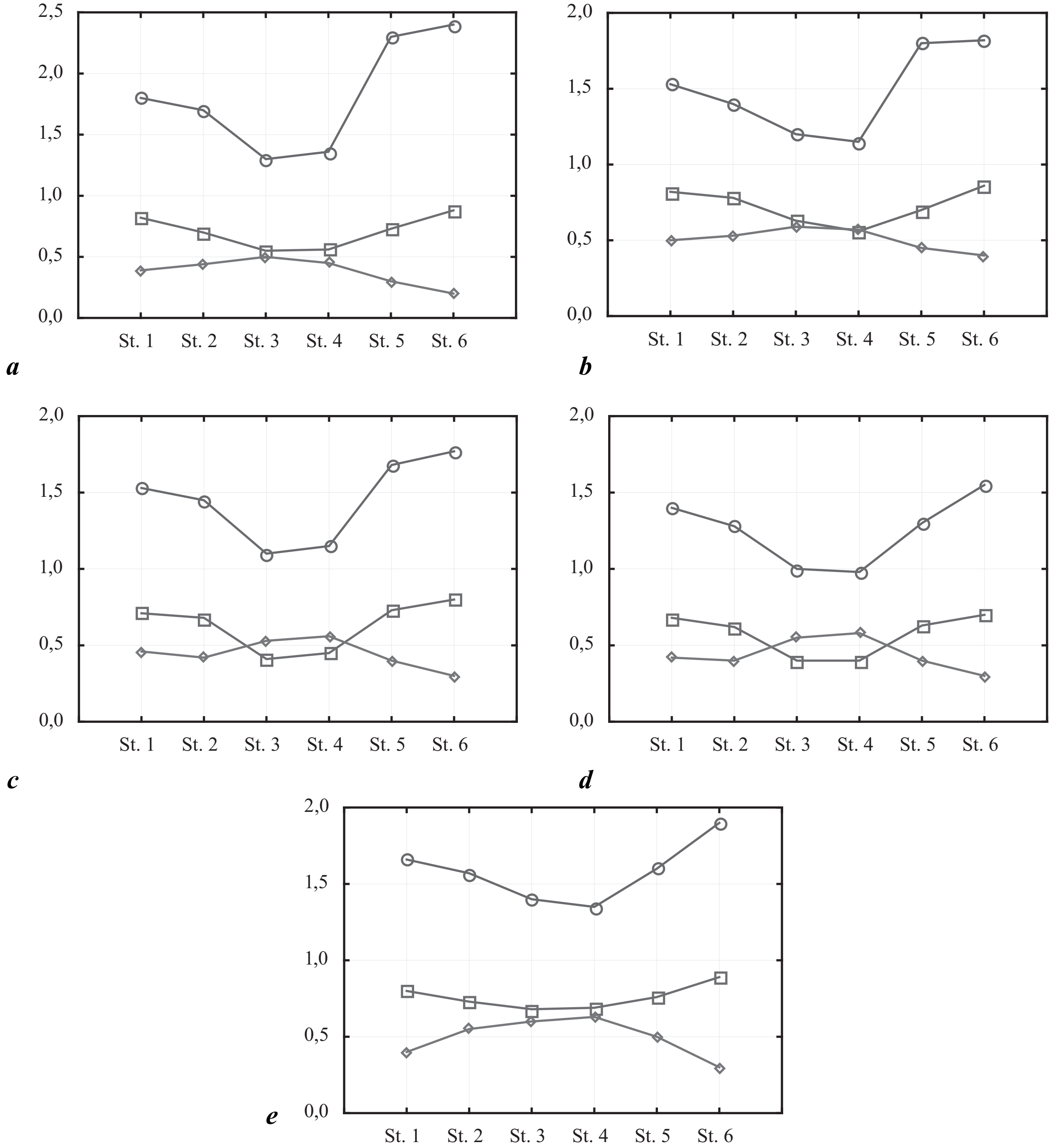


Fig. 8. Dynamics of cenotic zooplankton indices in „Kardzhali“ Dam
a **– April 2011,** ***b*** **– June 2011,** ***c*** **– July 2011,** ***d*** **– August 2011,** ***e*** **– March 2012**

Conclusions

Taxonomically the zooplankton of „Kardzhali“ Dam is diverse by species and is composed from 13 Rotatoria, 11 Cladocera and 5 Copepoda species. Quantitatively the Cladocera composed 68% from total biomass, Rotatoria 12% and Copepoda 22% correspondingly. The zooplankton community is of crustacean type.

The seasonal averages of zooplankton biomass are varying in the range 0.22 g.m^{-3} – 0.48 g.m^{-3}. There was a peak registered in the spring, while during the summer months the biomass decreased four times in comparison to the spring. In the autumn again an increase was registered.

The vertical distribution is distinguished by maximum in epilimnion, including 80–90% from total biomass, which is result of combined influence of light, temperature and oxygen factors.

The dominance of Cladocera over Copepoda (3:1), indicated high concentration of their trophic basis – phytoplankton.

From the dam and from the transitional reservoir zone towards the locality of the largest sturgeon farming facility both indices for species diversity after Shannon and for evenness after Pielou decreased under the influence of anthropogenic impact, but the degree of dominance in the community after Simpson increased. The zooplankton community demonstrated an especially low stability during July and August in the region of cage farming facility, most probably due to more intensive fish feeding and increased water temperature.

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