Bulgarian Journal of Agricultural Science, 17 (No 4) 2011, 501-511
Agricultural Academy

COMPOSITION AND ABUNDANCE OF ZOOPLANKTON IN KARDZHALY RESERVOIR

I. TRAYKOV[1], B. BOYANOVSKY[1] and M. ZIVKOV[2]
[1] *Sofia University "St. Kl. Ohridski", Dep. of Ecology and EP, Faculty of Biology, BG - 1164 Sofia, Bulgaria*
[2] *Bulgarian Academy of Sciences, Institute of Zoology, BG - 1000 Sofia, Bulgaria*

Abstract

TRAYKOV, I., B. BOYANOVSKY and M. ZIVKOV, 2011. Composition and abundance of zooplankton in Kardzhaly reservoir. *Bulg. J. Agric. Sci.,* 17: 501-511

The zooplankton community structure in "Kardzhaly" reservoir (South-East Bulgaria) was studied from July 2000 to November 2002. The seasonal cycles and population dynamics of the main taxonomic groups are described and discussed. The zooplankton community was composed of 12 species of Rotifera, 13 species of Cladocera, 7 species of Copepoda, 1 species of Ostracoda, 1 species of Cnidaria (Coelenterata), 1 species of Hydracarina and 1 species of Ciliata. The abundance of the zooplankton increases, 5 times on average, between the limnetic and the riverine zone of the reservoir. The Copepoda dominated the limnetic zone, closely followed by Cladocera, while in the transitional and the riverine zones the opposite was true. The zooplankton community was mostly crustacean, with the following perennial species: *Kellicottia longispina* and *Keratella cochlearis* from the Rotifera; *Daphnia longispina, Bosmina longirostris* and *Bosmina coregoni* from the Cladocera, as well as *Cyclops vicinus, Eudiaptomus gracilis* and the nauplii and copepodites of the Copepoda. Some relationships were found between the trophic state, the reservoir exploitation and the zooplankton community.

Key words: zooplankton, trophic state, seasonal dynamics, spatial heterogeneity

Introduction

Deep valley reservoirs are characterized by an elongated morphometry and pronounced longitudinal physical and chemical gradients imposed by the river inflow (Lind et al., 1993). The existence of such gradients in water quality and trophic state in reservoirs influences the horizontal distributions of phytoplankton (Fernandez-Rosado et al., 1994; Hejzlar and Vyhnalek, 1998) and zooplankton (Seda and Devetter, 2000; Fernandez-Rosado and Lucena, 2001) along the reservoir axis. Zooplankton communities are highly sensitive to environmental variation. As a result, the changes in their abundance and composition can provide important indications of environmental change or disturbance (Gannon and Stemberger, 1978; Bays and Crisman, 1982; Pejler, 1983; Guntzel et al., 2002). Nonetheless, variable responses of zooplankton to thophic status are common (Hanson and Peters, 1984, Ravera, 1996; Pinto-Coelho et al., 2005). Naidenov and Baev (1987) suggested,

[1]*E-mail: itraykov@biofac.uni-sofia.bg*

that the gradient of the planctonic communities along the reservoirs reflects their succession according to the trophic state in different zones of the reservoirs. Several works have been published in the last decade concerning Kardzhaly Reservoir: the spatial heterogeneity of physical and chemical parameters and their effect on trophic state (Traykov et al., 2003), on the influence of the exploitation regime and the environmental factors on the spatial changes of the zooplankton abundance (Traykov et al., 2005), on the factors, determining the trophic state of reservoir (Traykov, 2005) and on the phytoplankton composition (Belkinova et al., 2007). The aim of this paper is to present data on the composition and abundance of the zooplankton in Kardzhaly reservoir, and to analyze its temporal and spatial distribution in relation to the trophic state gradient in the reservoir.

Materials and Methods

Kardzhaly reservoir is located in southeast Bulgaria at $41^{o}37'$ N latitude and $25^{o}20'$ E longitude. It is the second largest (V=532.9 x 106 m^3; A=16.07 km^2), deep (Zmax=74, Zm=33), hydroelectric (106.4 MW) impoundment in Bulgaria with watershed area of 1882 km^2. Average theoretical residence time is approximately 200 days. The reservoir consists of a major basin receiving waters from Arda River and an embayment on the inflow of Borovitsa River. The major basin is morphometrically divided into three subbasins: deep-broad part, canyon-shaped part and shallow broad part, corresponding respectively to lacustrine, transitional and riverside zones in the reservoir. Arda River supplies ca. 90 % of the reservoir's annual water load.

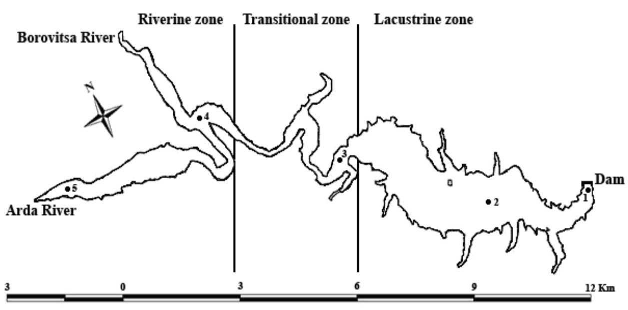

Fig. 1. Map of Kardzhaly reservoir with positions of the sampling stations

Sampling was carried out at 5 stations (Figure 1). Sixteen observations were conducted in the lacustrine zone (eight occasions in 2001 and as many in 2002), 14 in the transitional zone, and 11 in the riverside zone of the reservoir.

Integrated samples from the epilimnion were collected for physicochemical analyses using standard methods and equipment (Wetzel and Likens, 2000). On site measurements of water transparency (Secchi disc visability), dissolved oxygen (WTW OXI 196), electrical conductivity and pH (HI 98129) were conducted. Chemical analysis of water samples included total phosphorus (TP) and total nitrogen (TN) concentrations (colorimetrically after CracTest digestion in autoclave, MERCK – PMB methods 14848 and 14773, correspondingly), chlorophyll-a (acid corrected, ISO 10260) and total alkalinity (ISO 9963-1. 2000). Non-algal turbidity (NAT, m^{-1}) was calculated as: 1/Secchi – 0.025[Chlorophyll-a] according to Walker (1985).

The zooplankton samples were collected with quantitative plankton net ("Juday" – 120 µm mesh size) by averaging two vertical hauls taken from the whole depth at the station. The samples were fixed with formaldehyde to a final concentration of approximately 4%. Zooplankton was counted and identified microscopically in a counting chamber according to the procedures described in Harris et al. (2000). All taxa were identified down to the lowest possible taxonomic level.

Descriptive statistics were conducted for the studied variables. All analyses were performed using STATISTICA 6.0 software.

Results and Discussion

Physicochemical environment

We present data on selected physical and chemical variables at the different sampling stations in

Table 1

Average values of the main physicochemical variables along the reservoir

	Sampling stations				
	1	2	3	4	5
SD m^{-1}	3.52	3.36	2.61	1.8	1.6
pH	8.01	7.98	7.92	7.85	7.96
EC $\mu S.cm^{-1}$	190.4	188.6	172.2	167.5	180.1
DO $mg.l^{-1}$	9	9.2	9.5	10	9.5
TA $meq.l^{-1}$	1.26	1.24	1.17	1.2	1.24
TP $mg.l^{-1}$	0.075	0.06	0.125	0.129	0.112
DIN $mg.l^{-1}$	0.66	0.6	0.44	0.64	0.63
Chl-a $\mu g.l^{-1}$	5	4.8	6	8.5	12.7
NATm^{-1}	0.185	0.215	0.401	0.584	0.421
n^*	16	16	14	14	11

*- number of observations

Kardzhaly reservoir (Table 1). Kardzhaly reservoir is a warm monomectic water body with relatively long period of stratification – nine months. The stratification pattern and the morphometric characteristics of the reservoir determine the pronounced longitudinal differences of the main physicochemical parameters. The ionic ration of N: P changes from 30 in the riverside zone to 50 in the lacustrine one, indicating that phosphorus is most likely the limiting nutrient.

The trophic state of the reservoir also changes from eutrophic to slightly mesotrophic between the inflow and the dam part of the reservoir (Traykov et al., 2003).

Zooplankton composition

The total number of zooplankton identified in the reservoir was 36 taxa (at genus and species level), of which: 12 Rotifera, 13 Cladocera, 7 Copepoda, 1 Ostracoda, 1 Cnidaria (Coelenterata), 1 Hydracarina and 1 Ciliata (Table 2). The taxa identified show a wide ecological valence and are commonly distributed in the big reservoirs in Bulgaria.

Although the reservoir is characterized with relatively small number of observed taxa in comparison to the rest of the Bulgarian reservoirs - 109 species (Naidenow, 1984), it still has the highest taxa richness compared to the reservoirs situated further down the river course.

This has already been noted by Naidenow (1984), who states that the reservoirs from the Lower Arda River Cascade have the poorest species composition in Bulgaria due to the short retention time of the reservoirs. As the retention times and the observed taxa are as follows: for the Ivailovgrad Reservoir – 31 days and 12 species, for the Stouden kladenec Reservoir – 120 days and 25 species, and for the Kardzhaly Reservoir – 205 days and 36 taxa, we can confirm the relationship between the two parameters. Although, 2 new species have been identified recently in Ivailovgrad Reservoir (Kozuharov, personal communication), the relationship still holds true.

The perennial species among the zooplankton are Rotifers *Kellicottia longispina* and *Keratella cochlearis,* the Cladocerans *Daphnia longispina, Bosmina longirostris* and *Bosmina coregoni*, as well as the Copepods *Cyclops vicinus* and *Eudiaptomus gracilis*.

Table 2
Zooplankton taxa found in the pelagic zone of Kardzhaly reservoir

CILIATA	*Daphnia galeata* Sars
Vorticella sp.	*Daphnia s. lat. longispina* O.F.Muller
CNIDARIA	*Daphnia sp. juv.*
Craspedacusta sowerbyi	*Ceriodaphnia quadrangula* (O.F.Muller)
ARACHNIDA	*Ceriodaphnia reticulata* (Jurine)
Hydracarina sp.	*Leptodora kindti* (Focke)
ROTIFERA	*Bosmina s. lat longirostris* O.F.Muller
Trichocerca sp.	*Bosmina coregoni* Baird
Brachionus sp.	*Leydigia s.str. leydigii* Leydig
Keratella cochlearis (Gosse)	*Chydorus sphaericus* O.F.Muller
Keratella quadrata frenzeli (Eckstein)	*Alona sp.*
Keratella quadrata quadrata	**COPEPODA**
Kellicottia longispina (Kellikott)	*Cyclops vicinus* Uljanin
Synchaeta sp.	*Acanthocyclops robustus* (Sars)
Asplanchna priodonta Gosse	*Acanthocyclops vernalis* (Fisher)
Asplanchna sp.	Thermocyclops crassus (Fisher)
Filinia longiseta (Ehrenberg)	*Diaptomus castor* Jurine
Polyarthra dolichoptera Idelson	*Eudiaptomus gracilis* (Sars)
Polyarthra vulgaris Carlin	*Copepodites cyclopoida*
CLADOCERA	*Nauplii*
Diaphanosoma brachiurum Lieven	**OSTRACODA**
Daphnia s. lat. pulex Leydig	*Ostracoda spp.*
Daphnia cuculata Sars	

Zooplankton abundance

The zooplankton abundance increased approximately six times between the lacustrine and the riverside zones in the reservoir (Figure 2). The highest mean abundance for the period of investigation was encountered at station 5 – 26300 ind.m^{-3}, and the lowest – at station 2 – 4700 ind.m^{-3}. The total numbers of the zooplankton in 2002 decreased between stations 5 and 4 more than twice (to 10300 ind.m^{-3}), and between stations 4 and 3 by 1/3 – (6300 ind.m^{-3}).

A slight increase to 5600 ind.m^{-3} was observed at station 1, due to a combined effect of the specific morphometric, hydrodynamic and hydrochemical parameters of the region close to the dam. The main differences in the mean annual zooplankton numbers between 2001 and 2002 (as well as between stations) are observed in the riverside zone of the reservoir. In 2001 between stations 5 and 2 the zooplankton abundance decreased steadily from 13 000 ind.m^{-3} to 5 900 ind.m^{-3} and stayed more or less stable further on to the dam station. The most pronounced differences were observed in 2002 between stations 5 and 4, with a decrease from 42 900 ind.m^{-3} to 10 300 ind.m^{-3}. The abundance at stations 1 and 4 remained the same as in 2001, while almost a double decrease of the abundance was observed at stations 2 and 3 in comparison to those observed in 2001.

Although there is an increase of the total zoo-

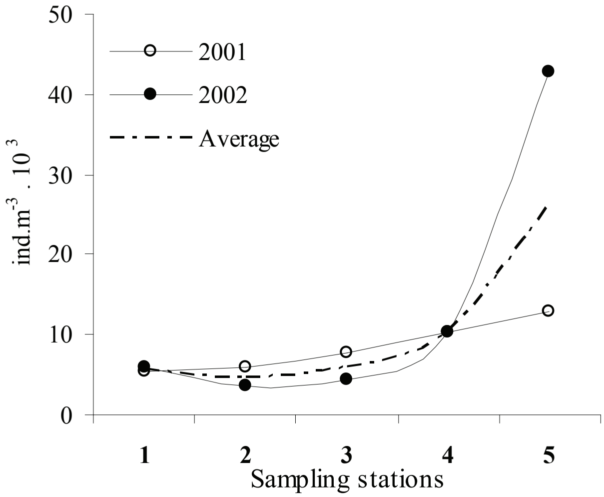

Fig. 2. Changes in the annual abundance of the zooplankton in the five sampling stations and between the years of observation

plankton numbers along the reservoir, different trends are observed in the changes of the annual abundance of the zooplankton groups (Figure 3).

Rotifera: The abundance of *Rotifera* varies broadly. In 2001 the density ranged from 4 to 6300 ind.m^{-3}, and in 2002 from 7 to 17 000 ind.m^{-3}. The lowest densities were found in winter in the lacustrine zone and the maximum – during the summer in the riverside zone. The mean annual abundance of the Rotifera declines approximately three times between sampling stations 5 and 1 (to 1300 ind.m^{-3}). At the same time, their relative abundance triples to aproximately 30% (Figure 3). The most abundant rotifers are *Kellicottia longispina, Filinia longiseta* and the representatives of the genus *Asplanchna*. *F. longiseta* develops predominantly in the lacustrine zone, while *Asplanchna* sp. and *K. longispina* mostly in the transitional and the riverine zones. The rest of the rotifers are found sporadically at sampling sites 4 and 5 in the transitional zone.

Cladocera: The *Sididae* family appears in the reservoir only at water temperatures higher than 14^{o}C, usually from late May to November. In 2001 the density of the family changed from 30 ind.m^{-3} at station 1 (June) to 5300 ind.m^{-3} at station 5 (October), while in 2002 - from 5 to 3700 ind.m^{-3}, correspondingly for November (station 1) and June (station 5). The mean annual abundance of the family is relatively constant along the reservoir, with a slight increase in station 5. Their relative abundance decreases steadily between the lacustrine (14%) and the riverside zones (6.5%). We have observed a consecutive development of the families *Sididae* and *Daphnidae* throughout the year, which according to Ferrara et al. (2002) could be attributed to competitive interactions between the species. The most abundant from the *Daphnidae* family are *Daphnia s. lat. longispina* and *Daphnia cuculata,* while the occurrence of *Daphnia s. lat. pulex* is low all over the reservoir (Figure 3).

The genus *Ceriodaphnia* is sparsely represented, with a peak development in the summer at stations 4 and 5. The predaceous cladocerian *Leptodora kindti* is found between May and November throughout the reservoir, with a maximum in the transitional zone at the end of the period of stable stratification (September). In 2001 the density of the *Daphnidae* family changed between 20 ind.m^{-3} at station 3 to 6 000 ind.m^{-3} at station 4, while in 2002 from 54 to 12 000 ind.m^{-3} at station 5. The mean annual density increases between the dam and the river inflow more than 4 times to 3 000 ind.m^{-3}, while the maximum of their relative abundance is at station 3 – 23% and gradually declines toward stations 1 and 5 to 13% and 11%, correspondingly. The abundance of the *Bosminidae* family is mostly formed by the *Bosmina longirostris,* which is one of the most important species in the transitional zone. Its lowest density in 2001 was at station 1 – 5 ind.m^{-3} (February), and the maximum on July at station 3 – 10 800 ind.m^{-3}. In 2002 the corresponding figures were (21 ind.m^{-3}) in April at station 4 and (95 100 ind.m^{-3}) at station 5 in June. The family is characterized with the strongest longitudinal gradient of its mean annual abundance, with an increase of more than 60 times between the lacustrine and the fluvial part of the reservoir (Fig. 3). The density increases from 200 ind.m^{-3} to 12 300 ind.m^{-3}, and the relative abundance – from 3.5% to 47%. The co-existence of the *B. coregoni*

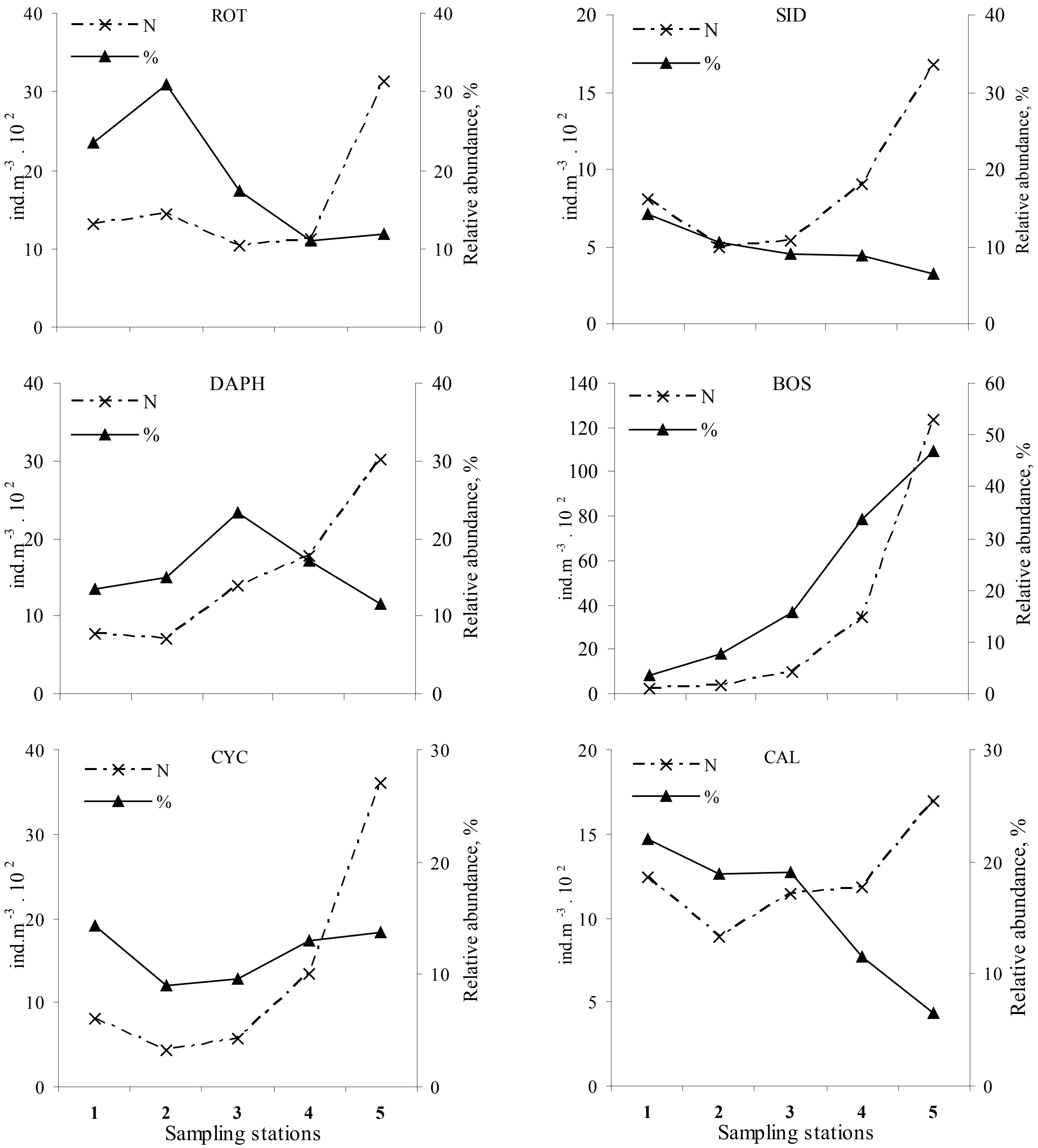

Fig. 3. Density variations and relative abundance of the major components of the zooplankton in the five sampling stations. ROT - Rotifera; DAPH - Daphnidae; SID - Sididae; BOSM - Bosminidae; CYC - Cycolpoida; CAL - Calanoida

and *B. longirostris* in Kardzhaly reservoir is due to the highly pronounced longitudinal gradients of the physicochemical and biological variables along the reservoir, as well as with depth. The cold hypolimnetic waters in the lacustrine zone provide the environment for the development of *B. coregoni* even during the summer months, when the species of the family develop mostly in the hypolimnion. The co-existence of the two species, according to Ravera (1996) is due to the fact, that *Bosmina coregoni* is more likely to be crio-stenothermic species from the central and northern European regions, but not a strict indicator of oligotrophic conditions, as described by Mikulski (1978) and Karabin (1985b). As typical bento-planktonic dwellers, the species of the fam. *Chydoridae* are a minor component of the plankton. The density of *Chydorus sphaericus* is maximal in the riverside zone, while *Leydigia s. str. leydigii* prevails in the lacustrine part. The peak of the *Chydoridae* family was in July 2001 (80 ind.m^{-3}), with mean values seldom exceeding 10 ind.m^{-3} for the lacustrine and 30 ind.m^{-3} for the riverside zone.

Copepoda: The species from sub-order *Cyclopoida* are with highest densities in the riverside zone (station 5) – 17 400 ind.m^{-3} (June 2002). The density of the sub-order gradually decreases toward the dam. The changes in the numbers of the cyclopoids along the reservoir reflect the gradient of the trophic state between the riverside and the lacustrine zones (Karabin, 1985a). The prevalence of sub-order *Cyclopoida* over sub-order *Calanoida* in the riverside zone is determined by the eutrophic state of this part of the reservoir. The co-existence of the *Acanthocyclops vernalis* and *Acanthocyclops robustus* in the reservoir is worth noting, as both species have different environmental requirements. This, again, is a result of the highly diversified habitat in the big dendrite reservoirs. The sub-order *Calanoida* is represented mostly by *Eudiaptomus gracilis.* The abundance of the sub-order was relatively stable along the reservoir, with minimal densities of 30 ind.m^{-3}, and maximal - 5800 ind.m^{-3} both at station 1 on February and July, 2001. The mean annual density of the sub-order changes between 1200 ind.m^{-3} at station 1 to 1700 ind.m^{-3} at station 5, which in contrast to the overall increase of the zooplankton abundance, leads to a decrease in their relative abundance from 22% to 6%, correspondingly. Similar to *B. coregoni*, *Diaptomus castor* is a typical northern species, reported occasionally for water bodies in south Bulgaria (Naidenov, 1966). The geographic locations of the big southern reservoirs in Bulgaria, which serve as resting points for migratory birds, determine the possibilities for avail transfer and development of typical northern species.

Other planktonic organisms: The ciliates are frequently observed in the upper parts of the reservoir, attached to detritus particles, and, in some occasions, as an epibionts on different species from order *Copepoda*. Throughout the period of stable stratification and temperatures above 24^{o}C (June - August) the freshwater jellyfish *Craspedacusta sowerbyi* is found in the limnetic zone of the reservoir. According to Jankowski and Ratte (2001) *C. sowerbyi* is effective predator, which at higher abundances could alter the structure and the density of the crustacean zooplankton. Taking into account the relatively low densities of the freshwater jellyfish and the predatory Cladocera *Leptodora kindti,* we could expect their share into the predatory press to be low in comparison to that exerted by the zoo-planktivorous fish. Their significance as predators could be higher in the side arms of the reservoir, where their abundance could be higher than in the plelagial. A singular observation of *Hydracarina sp*. was made in the riverside zone of the reservoir in June 2002 at the station close to the Arda river inflow.

Zooplankton seasonal trends

Seasonal variation in the abundance of the major zooplankton groups showed some differences between the lacustrine, transitional and riverside zones in the reservoir (Figure 4).

The zooplankton numbers are low in winter, increase in spring and decline again in late autumn.

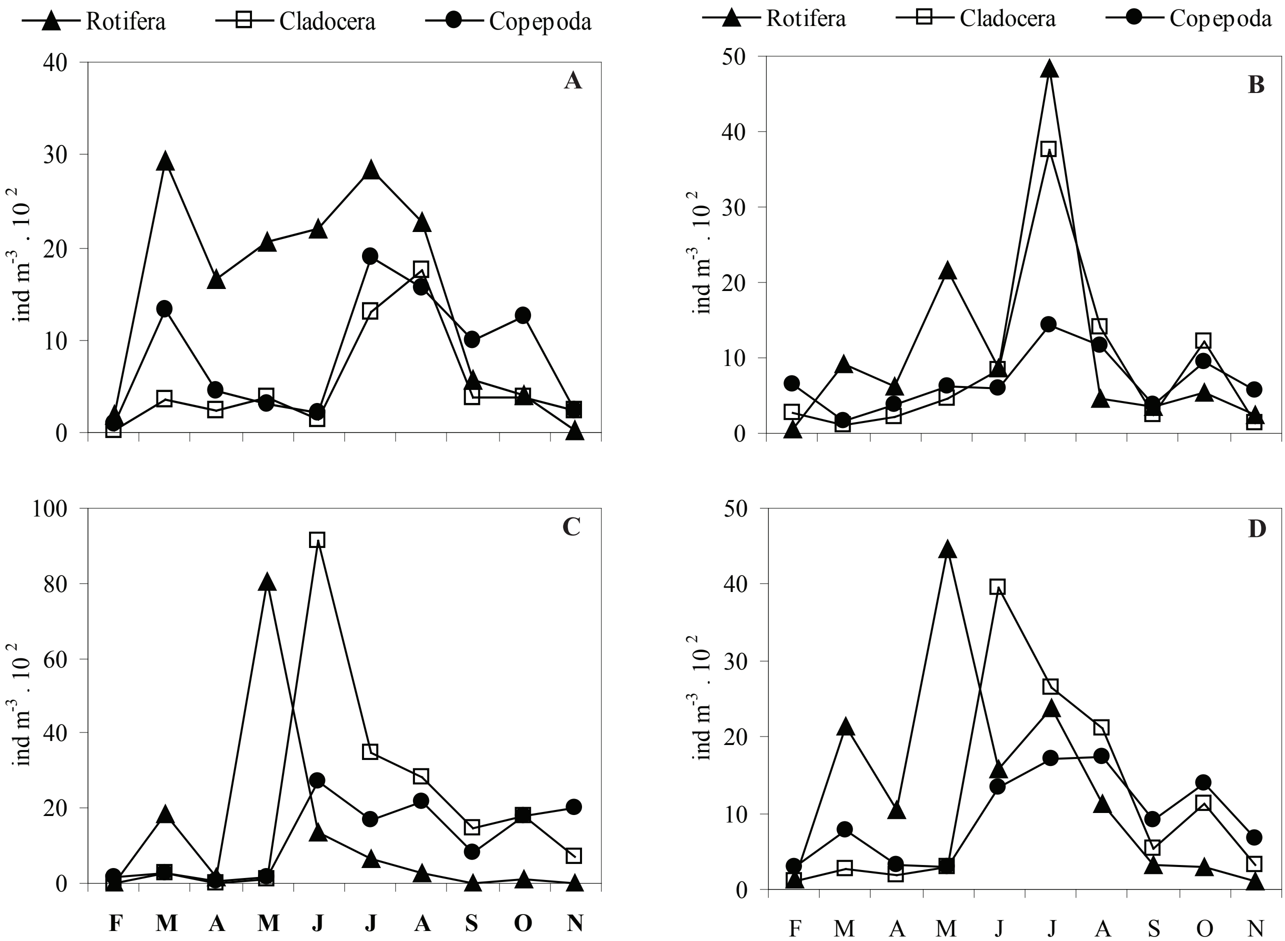

Fig. 4. Density variations of zooplanktonic groups in the different zones of the reservoir during the study period: A) - lacustrine zone; B) - transitional zone; C) - riverine zone and D) - average for the reservoir

A spring density maximum (March) is observed at all stations, primarily in the development of *Rotifera* and *Copepoda* – cyclopoida and nauplii. In April we have observed a sharp decline in the zooplankton abundance at all stations. This is most likely due to the rapid increase of the water level in the reservoir (on average 6.5 m), consequently of the volume of the epilimnion. This leads to dilution of the zooplankton numbers to a seemingly lower abundance.

After the stabilization of the water level and the increase in temperature, a second summer peak in the zooplankton numbers is observed along the reservoir. The timing of this peak shifts with approximately a month toward the dam – from May-June in the riverside to July-August in the lacustrine zones.

Zooplankton spatial heterogeneity

The vertical distribution of the zooplankton was studied in the lacustrine zone of the reservoir. As in the case with most Bulgarian reservoirs, an epilimnetic maximum was observed (Lyudskanova, 1967; Naidenow, 1984; Naidenow and Baev, 1987; Kozuharov, 1996). On average, more than 80% of the zooplankton was concentrated in the upper mixed layer.

The *Rotifera* prevailed slightly in the hypolimnion – 60%, *Calanoida* and *Cyclopoida* were con-

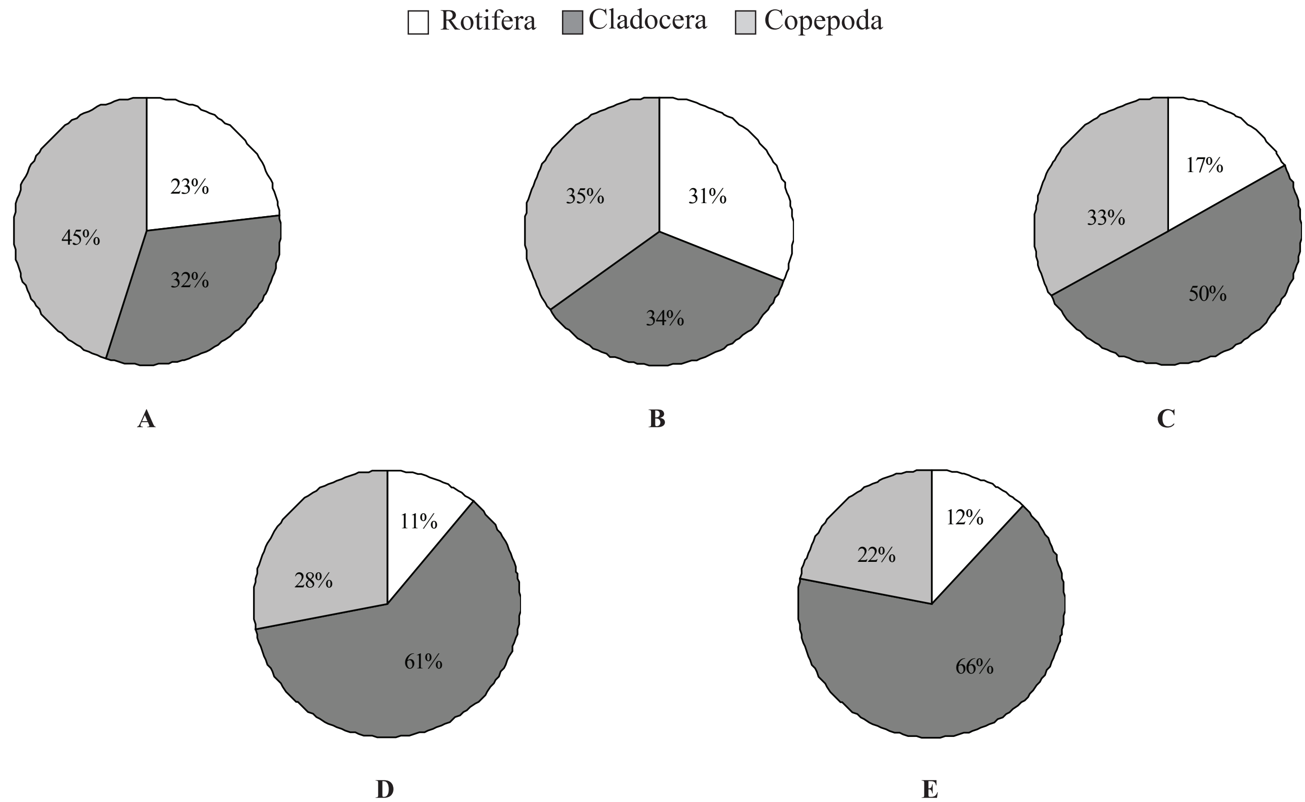

Fig. 5. Variation of the average density of zooplanktonic groups at different stations in the reservoir during the study period: A) - station 1; B) - station 2; C) - station 3; D) - station 4 and E) - station 5

centrated exclusively in the epilimnion, with more than 90% and 80% of their numbers found there. Throughout the summer the daphniids prevailed in the epilimnion (76%), while with the autumnal deepening of the termocline, 56% of its numbers were found in deeper layers. The only component of the zooplankton which develops predominantly in the hypolimnion is the *Bosminidae* family – approximately 70%.

The main reason for the epilimnetic distribution of the zooplankton could be attributed to the strong metalimnetic gradients of the temperature and oxygen. The long period of stratification facilitates the establishment of extreme metalimnetic minimum of the oxygen concentration, with a formation of anoxic layer of moderate thickness (7m) (Traykov, 2005). This confirms the findings of Hrabacek (1984) and Ravera (1996), according to which the main factor determining the epilimnetic development and the vertical migrations of the zooplankton in the reservoirs is the depth distribution of the oxygen.

The horizontal distribution of the zooplankton along the reservoir, both in space and in time, reflects the gradient in the physical and chemical variables and the corresponding increase in the trophic state from the dam to the Arda river inflow.

In the reverie and the transitional zones, the Cladocerans are the most significant component of the zooplankton, followed by the Copepods and the Rotifers (Figure 5). This type of distribution of the main groups is described by Naidenov (1984) as standard for the Bulgarian reservoirs. The author points an upper value of 63% for the relative abundance of *Cladocera*. In Kardzhaly reservoir, due to the mass development of family *Bosminidae,* this value is exceeded in the reverie zone (stations 5). In the lacustrine zone the relative abundance of order *Copepoda* increases, and at station 2 it equals sub-order *Cladocera*, while at station 1 it is with 25% higher. The relative abundance of the Rotifers was highest at station 2 (31%), probably due to the influence of the cage fish farm and the overall decrease in the density of the zooplankton.

The prevalence of order *Copepoda* at station 1 is determined mostly by the high densities of sub-order *Calanoida*. According to Karabin (1985a, b), the abundance of the Calanoids increases between the reverie and the lacustrine zones, parallel to the overall decrease of trophic state in this direction in the reservoirs. Our results also confirm the conclusions of Ravera et al. (1986) and McNaugh (1975) that state the abundance of the Cladocerans increases with the increase in the trophic state, both in time and space (Figure 5).

The food limited limnetic zone favors the development of k-strategy (*Calanoida*) than the smaller r-strategy zooplankters (fam *Bosminidae*), which prevail under unstable conditions in the reverie and the transitional zones. Additional prerequisite for the fast development of the fam. *Bosminidae* (*Bosmina longirostris)* in the upper parts of the reservoir is their capability to ingest detritus particles, together with the attached bacteria, as an alternative food source (Muller, 1985).

Although there are no previous data for the composition and abundance of the zooplankton in Kardzhaly reservoir, our results confirm the general trends observed in deep reservoirs and lakes. Both, composition and abundance indicate that the different zones in Kardzhaly reservoir have features corresponding to the trophic gradient – from moderate to high productivity.

Acknowledgments

In Memory of my great teachers and friends. Thank you for your supervision and support throughout the years. You will always be remembered.

This research was part of the PhD thesis of the first author. The authors express their gratitude to Assoc. Prof. D. Kozuharov from the department of General and Applied Hydrobiology of Faculty of Biology, Sofia University for his help with the identification of the material.

References

Adrian, R., 1998. The timing of warming- an important regulator of change in lake plankton communities. In: D.G. George et al. (eds), Management of lakes and reservoirs during global climate change. *Kluwer Academic Publishers*: *NATO ASI Series,* **42:** 205-222.

Bays, J. and T. Crisman, 1982. Zooplankton and trophic state relationships in Florida lakes. *Can. J. Fish. Aquat. Sci*., **39:** 1813–1819.

Belkinova, D., R. Mladenov, I. Dimitrova-Dyulgerova, S. Cheshmedjiev and I. Angelova, 2007. Phytoplankton research in Kurdzhali Reservoir. *Phytologia Balcanica,* **13**: 47–52.

Fernándes-Rosado, M., J. Lucena and F. Niell, 1994. Spacetime heterogeneity of the chlorophyll-a distribution in La Concepción Reservoir (Istán, Málaga). Representative models. *Arch. Hydrobiol*., **129**: 311-325.

Fernándes-Rosado, M. J. and J. Lucena, 2001. Space time heterogeneities of the zooplankton distribution in La Concepción Reservoir (Istán, Málaga; Spain). *Hydrobiologia*, **455:** 157-170.

Gannon, J. and R. Stemberger, 1978. Zooplankton (especially crustaceans and rotifers) as indicators of water quality. *Trans. Am. Microsc. Soc*., **97**: 16–35.

Güntzel, A., O. Rocha and T. Matsumura-Tundisi, 2002. Zooplankton Assemblages as Indicators of Spatial Heterogeneity and Temporal Variability in Ibitinga Reservoir, Middle Tiete River, SP, Brazil. 4th International Conference on Reservoir Limnology and Water Quality. Institute of Hydrobiology-Academy of Sciences of the Czech Republic, August 2002

Hejzlar, J. and V. Vyhnálek, 1998. Longitudinal heterogenity of phosphorus and phytoplankton concentrations in deep valley reservoirs. *Internat. Rev. Hydrobiol*., **83:** 139-146.

Hanson, J. and R. Peters, 1984. Empirical prediction of crustacean zooplankton biomass and profundal macrobenthos biomass in lakes. *Can. J. Fish. Aquat. Sci.,* **41**: 439–445.

Harris, R., P. Wiebe, J. Lenz, H. Skjoldal and M. Huntley (eds)., 2000. ICES Zooplankton Methodology Manual. *Academic Press*, 684 pp.

Hrbacek, J., 1984. Ecosystems of the European men-made lakes. – In: Taub, F.B., edt. Lakes and Reservoirs, *Elsevier Science Publishers*, B.V., Amsterdam. pp. 267-290.

ISO 10260, 1992. Water quality - Measurement of biochemical parameters - Spectrometric determination of the chlorophyll-a concentration.

ISO 9963-1, 1994. Water quality - Determination of alkalinity. Part 1: Determination of total and composite alkalinity.

Jankowski, T. and H. Ratte, 2001. On the influence of the freshwater jellyfish *Craspedacustra sowerbii* on the zooplankton communities. *Verh. Internat. Verein. Limnol.,* **27**: 3287-3290.

Karabin, A., 1985 (a). Pelagic zooplankton (Rotifera + Crustacea) variation in the process of lake eutrophication. I. Structural and quantitative features – *Ekol.Pol.,* **33:** 567-616.

Karabin, A., 1985 (b). Pelagic zooplankton (Rotifera + Crustacea) variation in the process of lake eutrophication. II. Modifying effect of biotic agents – *Ekol.Pol.,* **33:** 617-644.

Kozuharov, D., 1996. Dynamics of quantitative parameters of the zooplankton in the system River Strouma – "Pchelina" Reservoir and influence of the ecotone zone on them. *Khidrobiologiya,* **40:** 55-64.

Lind, O., T. Terrell and B. Kimmel, 1993. Problems in reservoir trophic-state classification and implications for reservoir management. In: Straškraba, M., J.G. Tundisi and A. Duncan (Eds). Comparative reservoir limnology and water quality managament. *Kluwer Academic Publishers,* The Netherlands: pp. 55-67.

Lyudskanova, Zh., 1967. Changes in the abundance and biomass of the zooplankton of Batak Reservoir in the period 1963 – 1965. *Izvestiya na NIRSO – Varna*, **VIII**: 371 – 387 (Bg).

McNaugh, D., 1975. A hypothesis to explain the succession from calanoids to cladocerians during eutrophication. *Verh. int. Ver. Limnol*., **19:** 724-731.

Mikulski, J., 1978. Value of some biological indices in case histories of lakes. *Verh. int. Ver. Limnol.,* **20:** 992 - 996.

Muller, H., 1985. The niches of *Bosmina coregoni* and *Bosmina longirostris* in the ecosystem of Lake Constance. *Verh. int. Ver. Limnol.*, **22:** 3137-3143.

Naidenow, W., 1966. Katalog der Copepodenfauna Bulgariens. *Bull. Inst. Zool. Et muse Sofia,* **21:** 109-138.

Naidenow, W., 1984. Composition and ecology of the zooplankton of Danube River and the continental water bodies in Bulgaria. – *Avtoreferat of DSc Thesis*, Institute of Zoology, BAS, Sofia. (Bg)

Naidenow, W. and N. Baev, 1987. Changes of the zooplankton parameters in the river to reservoir ecotone under anthropogenic influence. *Khidrobiologiya,* **31:** 3-14 (Bg).

Pejler, B., 1983. Zooplanktonic indicators of trophy and their food. *Hydrobiologia*, **101**: 111–114.

Pinto-Coelho, R., B. Pinel-Alloul, G. Ginette Methot and K. Havens, 2005. Crustacean zooplankton in lakes and reservoirs of temperate and tropical regions: variation with trophic status. *Can. J. Fish. Aquat. Sci.,* **62**: 348–361

Ravera, O., 1996. Zooplankton and trophic state relationships in temperate lakes. *Mem. Ist. Ital. Idrobiol.,* **54**: 195–212.

Seda, J. and M. Devetter, 2000. Zooplankton community structure along a trophic gradient in a canyon-shaped dam reservoir. *J. Plankton Res*., **22:** 1829-1840.

Traykov, I, B. Boyanovsky, M. Zivkov and G. Mirinchev, 2003. Spatial Heterogeneity of Physical and Chemical Parameters in Kardjaly Reservoir – Effect on Trophic State. In: *Proceedings of "Second International Conference Ecological Protection of the Planet Earth"*, June 2003, Sofia, p. 280-287.

Traykov, I., B. Boyanovsky, M. Zivkov and G. Mirinchev, 2005. Spatial and temporal changes in the zooplankton abundance of a valley shaped reservoir – influence of the exploitation regime and environmental factors. In: Chipev, Bogoev (edt). *Proceedings from the 1st national scientific conference on Ecology – Biodiversity – Ecosystems – Global problems*. pp. 347-355.

Traykov, I., 2005. Factors influencing the trophic state of Kurdzhali Reservoir. *PhD Thesis*. Sofia University "St. Kliment Ohridski", Sofia (Bg).

Walker, W., 1985. Empirical method for predicting eutrophication in impoundments. Report 3: Phase II – Model refinement. Technical Report E-81-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Wetzel R. and G. Likens, 2000. Limnological Analysis. *Springer,* 429 pp.

Received December, 1, 2010; accepted for printing June, 2, 2011.