Phytoplankton research in Kurdzhali Reservoir

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Dedicated to Assoc. Prof. Dr Stefan Draganov in honour of his 75th anniversary

Abstract. The species structure and quantitative development of the summer phytoplankton in Kurdzhali Reservoir have been studied. A total of 55 species was found, belonging to 6 divisions: *Cyanoprokaryota* – 13, *Chlorophyta* – 23, *Zygnemaphyta* – 5, *Dinophyta* – 2, *Euglenophyta* – 3, and *Bacillariophyta* – 9 species. The divisions *Chlorophyta* (41.8 %), *Cyanoprokaryota* (23.6 %) and *Bacillariophyta* (16.4 %) have shown the highest relative abundance. In the ecotone zone of river Arda – Kurdzhali Reservoir the species diversity and quantitative development of the phytoplankton are higher than in the Reservoir proper. The average phytoplankton biomass corresponds to levels characteristic for the boundary between oligo- and mesotrophic types of water basins.

Key words: biomass, biomonitoring, density, phytoplankton, species structure

Introduction

In order to regulate the large and greatly varying with the seasons water flow of river Arda, three large reservoirs have been built along its course: Kurdzhali, Stouden Kladenets, and Ivailovgrad. The water from these reservoirs is used for potable water supply, power generation and irrigation in farming.

Kurdzhali Reservoir is practically Bulgaria's second largest (in volume) water basin after Iskur Reservoir, and second deepest after Vucha Reservoir. It started functioning in 1962. It is situated northwest of the town of Kurdzhali and the dam wall is about 3 km away from the town. The length of Kurdzhali Reservoir is 29 km and the maximum depth at the dam wall ~100 m. The submerged area is about 1607–1721 ha and the water volume is 533 mln/m^3. The Reservoir water is used mostly for power generation, fish-breeding, irrigation, and recreation.

Although Kurdzhali Reservoir has been in existence for over forty-four years, it has yet to be thoroughly researched in a hydrobiological aspect. The only complex ecological research of the Reservoir was carried out by Traykov (2005). The results obtained on the basic hydrological, abiotic and biological factors were cited in several publications (Traykov & Boyanovsky 2003; Traykov & al. 2003, 2005). As regards the phytoplankton, for the first time data were gathered about the species variety and dynamics of their quantitative development (Traykov 2005).

The aim of the present research is to continue in a more comprehensive effort the study of the species diversity, structure, distribution, and quantitative development of the phytoplankton in Kurdzhali Reservoir, thus laying down a foundation for water-quality monitoring.

Material and methods

Phytoplankton samples were collected from the surface layer of Kurdzhali Reservoir in Meyer bottles (of 1l) twice in the summer (July and September, 2006). Sample collection took place at four stations, evenly distributed along the Reservoir (Fig. 1). The location of the stations is shown in Table 1, along with some hydrological and hydrochemical characteristics. A total of eight qualitative and eight quantitative samples was collected, processed and analysed.

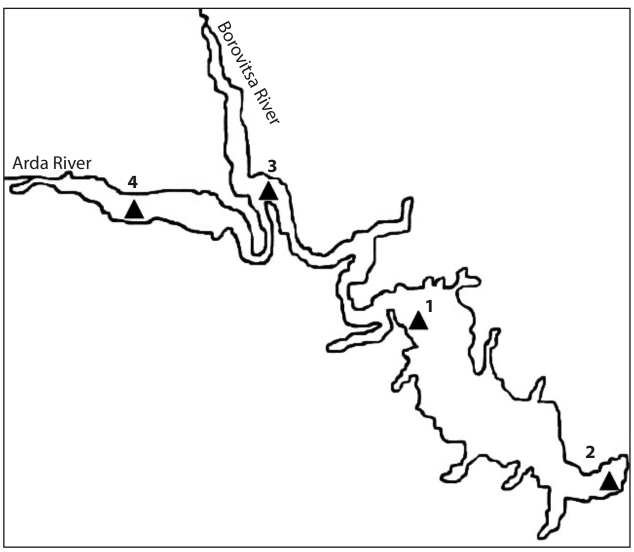

Fig. 1. Map of Kurdzhali Reservoir, with locations of the sampling stations:
no. 1, middle of Reservoir; **no. 2**, dam wall; **no. 3**, Reservoir tail end, river Borovitsa inlet; **no. 4**, Reservoir tail end, river Arda inlet.

The phytoplankton species structure was determined in parallel from fresh and conserved (in 4 % formol) samples, with a Carl Zeiss – Ergaval light microscope (400×), and listed down systematically.

The quantitative processing of phytoplankton followed the Protocol for Phytoplankton Counting (prEN 15204 2005). The quantity was determined by cell counting with a PZO Poland inverted microscope (100× and 400×). In order to calculate the total phytoplankton biomass in each sample, the biomasses of the separate populations were summed together. Species cell volumes were borrowed from tables for freshwater phytoplankton (Fedorov 1979), or calculated directly for separate species by the stereometric method (CEN TC230 WG2 TG3, 2006).

Table 1. Sampling stations, hydro-chemical and hydrological characteristics of Kurdzhali Reservoir.

Station no.	Date	GPS coordinates N, E	Temperature [°C]	Transparency [m]	O_2 [mg/l]	Saturation [%]	pH
1 (Middle of reservoir)	25.07. 2006	331 m 41°38′28″ 25°18′16″	25.1	3.5	8.4	107.6	9.23
	29.09. 2006	318 m 41°38′20″ 25°18′16″	20.5	3.2	8.62	99.0	8.24
2 (Dam wall)	25.07. 2006	337 m 41°37′55″ 25°20′24″	24	4.0	8.5	104.2	9.28
	29.09. 2006	337 m 41°37′55″ 25°20′23″	19.9	3.5	8.37	95.4	8.25
3 (Reservoir tail end, Borovitsa river inlet)	26.07. 2006	323 m 41°41′57″ 25°14′46″	25.7	3.0	9.12	108.1	9.3
	26.09. 2006	319 m 41°41′01″ 25°14′39″	20.4	2.80	7.14	82.7	7.76
4 (Reservoir tail end, Arda river inlet)	26.07. 2006	328 m 41°40′29″ 25°14′08″	25.7	2.45	9.94	122.5	9.23
	26.09. 2006	320 m 41°40′32″ 25°14′10″	20.5	2.80	7.38	84.4	7.84

Results

Taxonomic structure of the phytoplankton

In an earlier research of the phytoplankton in Kurdzhali Reservoir, 54 taxa were found, belonging to seven divisions: *Chlorophyta* – 25, *Bacillariophyta* – 15; *Cyanoprokaryota* – 7; *Euglenophyta* – 3; *Pyrrophyta* – 2, *Cryptophyta* – 1, and *Chrysophyta* – 1 (Traykov 2005). These data were based on the analysis of 34 phytoplankton samples taken from 5 Reservoir stations in the period 2000–2002.

We have found 40 algal species in the phytoplankton samples of July (Table 2). The following species have shown the highest relative abundance: green algae (*Chlorophyta* – 37.5 %), blue-green algae (*Cyanoprokaryota* – 27.5 %) and diatom algae (*Bacillariophyta* – 17.5 %) (Fig. 2). The remaining systematic groups – conjugates (*Zygnemaphyta*), dinoflagellates (*Dinophyta*) and euglenoids (*Euglenophyta*) – have participated in the phytoplankton with an insignificant number of species.

Most frequent across the Reservoir were the blue-green alga *Synechococcus elongatus*, the green alga *Ankyra judayi* Fott, the conjugate *Staurastrum gracile*, and the euglenoid *Trachelomonas rotunda*. At the tail end of the Reservoir, owing to the influence of river

Table 2. Taxonomic composition of the phytoplankton in Kurdzhali Reservoir – July and September 2006.

Taxon	Station No							
	1	2	3	4	1	2	3	4
	July				September			
Cyanoprokaryota								
Anabaena affinis Lemm.	+	+				+		
Anabaena solitaria Kleb.			+	+			+	+
Anabaena spiroides Kleb.			+	+				
Aphanizomenon flos-aque (L.) Ralfs	+		+	+			+	+
Aphanothece clathrata W. & G.S. West	+	+	+	+				
Chroococcus dispersus (Keissl.) Lemm.			+	+				
Chroococcus limneticus Lemm.			+	+				
Eucapsis alpina Clem. & Shantz								+
Gloeocapsa turgida (Kütz.) Hollerb.		+						
Microcystis aeruginosa (Kütz.) Kütz.			+	+	+	+		
Microcystis pulverea (H.C. Wood) Forti emend. Elenkin								+
Oscillatoria willei Gardner			+					
Synechococcus elongatus (Näg.) Näg.	+	+	+	+	+	+	+	+
Chlorophyta								
Ankyra judayi (G.M. Sm.) Fott	+	+	+				+	+
Coelastrum microporum Näg.								+
Coenochloris hindakii Komárek			+	+			+	+
Dictyosphaerium elegans Bachm.	+	+						
Dictyosphaerium pulchellum H.C. Wood			+				+	+
Elakatothrix genevensis (Reverd.) Hindák					+		+	+
Eudorina elegans Ehrenb.	+		+	+	+		+	+
Eutetramorus planktonicus (Korshikov) Bourr.								+
Monoraphidium pusillum (Printz) Komárk.-Legn.			+	+		+		
Oocystis borgei J. Snow					+		+	+
Oocystis lacustris Chodat			+	+			+	
Oocystis socialis Ostenf.		+						
Pandorina morum (O.F. Müll.) Bory	+						+	+
Pediastrum duplex Meyen	+	+	+	+	+	+	+	+
Pediastrum simplex Meyen	+		+	+	+	+	+	+
Quadricoccus ellipticus Hortob.								+
Scenedesmus bicaudatus Dedus.								+
Schroederia robusta Korshikov			+	+		+	+	+
Schroederia setigera (Schröd.) Lemm.	+	+	+	+	+		+	+
Schroederia spiralis (Printz) Korshikov					+			
Tetradesmus cumbricus G.S. West						+		
Trochiscia planktonica E.M. Lind & Pearsall	+							
Volvox aureus Ehrenb.	+							
Zygnemaphyta								
Closterium aciculare T. West					+	+	+	+
Closterium acutum Bréb.	+							+
Closterium venus Kütz. ex Ralfs							+	
Gonatozygon monotaenium de Bary					+			
Staurastrum gracile Ralfs	+	+	+	+	+	+	+	+
Dinophyta								
Ceratium hirundinella (O.F.Müller) Dujard.		+			+	+	+	+
Peridinium spp.			+	+	+			
Euglenophyta								
Euglena clara Skuja			+	+				
Euglena spp.								+
Trachelomonas rotunda Svirenko	+	+	+	+		+	+	+
Bacillariophyta								
Asterionella formosa Hassall			+	+		+	+	+
Cocconeis spp.					+			
Cymbella spp.	+							
Fragilaria capucina Desm.	+	+	+	+				
Fragilaria crotonensis Kitton	+	+	+	+	+	+	+	+
Melosira granulata (Ehrenb.) Ralfs			+		+	+		
Stephanodiscus hantzschii Grunov							+	+
Synedra acus Kütz.			+					
Synedra ulna (Nitzsch) Ehrenb.	+	+	+	+				

Most frequent (mass) species

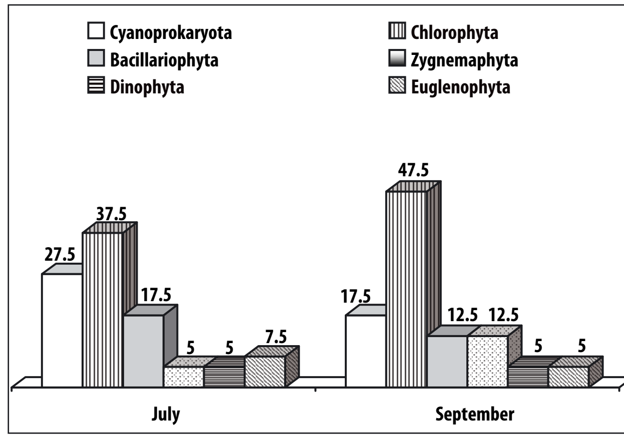

Fig. 2. Relative abundance of algal species (%) in Kurdzhali Reservoir.

Arda on the algal flora, this leading group was joined by: the blue-green algae *Anabaena solitaria* Klebahn, *Oscillatoria willei*, the green algae *Dictyosphaerium pulchellum*, *Oocystis lacustris*, *Eudorina elegans*, *Pediastrum duplex*, *P. simplex*, *Schroederia setigera*, and the diatom *Fragilaria crotonensis*.

Out of the four research stations, the greatest species variety was found at the stations in the ecotone zone of river Arda – Kurdzhali reservoir: Station no. 3–29 species and Station no. 4–24 species.

In September the number of species found was again 40 (Table 2). Compared to July (Fig. 2), the relative abundance of the green algae (47.5 %) and of the conjugates (12.5 %) has increased, while that of the blue-green (17.5 %) and of the diatom (12.5 %) algae has decreased. Dinoflagellates and the euglenoids were again represented by a small number of species (5.0 % each).

In September, the diatom *Fragilaria crotonensis* was the mass species across the Reservoir. In the open Reservoir (Stations no. 1 and no. 2), the blue-green alga *S. elongatus* still occurred frequently. At the tail end of the Reservoir (Stations no. 3 and no. 4), the leading species group was again different. Some of the mass species characteristic for July have dropped out, while the blue-green algae *Anabaena solitaria, Aphanizomenon flos-aquae*; the green algae *Eudorina elegans*, *Pediastrum simplex* and the diatom *Fragilaria crotonensis* were still frequently observed. A new component of the mass-present species that came in with the river water was the minute diatom *Stephanodiscus hantzschii*, which was not found in July.

As compared with July, the following species have entirely disappeared from the phytoplankton, or were very rare: the green algae *Ankyra judayi*, *Dictyosphaerium* *pulchellum*, *Pediastrum duplex* and *Schroederia setigera*, the conjugate *Staurastrum gracile*, the euglenoid *Trachelomonas rotunda,* and the diatom *Synedra ulna*.

In September again, richer in species variety were the Stations no. 3 and no. 4 in the ecotone zone of river Arda – Kurdzhali Reservoir, with 23 and 29 species respectively, while in the Reservoir proper (Stations no. 1 and no. 2) they had 17 and 15 species respectively (Table 2). Analyzing the results on the phytoplankton species variety and distribution in 2002, Traykov (2005) has also noted a decrease in the taxa representation from the Reservoir tail end (38) towards the dam wall (23).

Quantitative development of the phytoplankton (density and biomass)

According to the published data, phytoplankton density in Kurdzhali Reservoir varies from 250×10^3 cells/l to 6.9×10^6 cells/l, increasing about fourfold from the dam wall towards the tail end (Traykov 2005).

We have found that in July phytoplankton density varied from 2.15×10^6 cells/l to 3.79×10^6 cells/l (Fig. 3). Density was lowest close to the dam wall (Station no. 2) and highest at the river Arda inlet (Station no. 4).

Dominant for the phytoplankton density in July were the blue-green algae: from 66.8 % to 72.2 % across the Reservoir. They were represented mostly by the *Synechococcus elongatus* species. For example, at Station no. 1 this species accounted for 70.3 % of the total density. In spite of this, its share of the biomass was insignificant (7.1 %), because *S. elongatus* is of the nanoplankton kind. Second in significance were the diatoms (*F. crotonensis* and *S. ulna*), which at Stations no. 3 and no. 4 reached 22.5 % and 17.4 % respectively of the total density. Only at Station no. 2 the green algae (25.8 %) came second in relative density, with *A. judayi* as the most frequent species.

The biomass values for July follow the density distribution (Fig. 3). The lowest density of 0.61 mg/l was found at the dam wall, and the highest again at the tail end of the Reservoir (Stations no. 3 and no. 4): 0.93 and 0.95 mg/l respectively.

At the dam wall and in mid-Reservoir, the highest biomass percentage was that of the green algae (no. 1–36.9 % and no. 2–62.3 %). Diatoms dominated in the lower water clarity at the tail end of the Reservoir (Station no. 3–50.5 % and no. 4–41.1 %). The blue-green algae constituted a high percentage of the biomass at the Reservoir centre (Station no. 2–23.0 %) and at the river Arda inlet (Station no. 4–22.0 %).

In September, the quantitative development of phytoplankton was higher. Density varied from 2.88×10^6 cells/l to 8.44×10^6 cells/l, and the biomass from 1.13 mg/l to 4.66 mg/l (Fig. 4). In the direction from the dam wall towards the ecotone zone there was again a tendency for quantitative increase. The values for density and biomass at the river Arda inlet were three to four times higher than those at the dam wall, which coincides with the conclusions of Traykov (2005).

The lowering of water temperature by approximately 5°C in September has lead to intensive quantitative development of the diatoms which prefer colder temperatures and which displaced the blue-green algae. Over 50 % of the total density at Stations no. 1 and no. 2 was formed by *F. crotonensis*. At Station no. 1 *F. crotonensis* reached 2.33×10^6 cells/l, which accounted for 93.3 % of the total biomass.

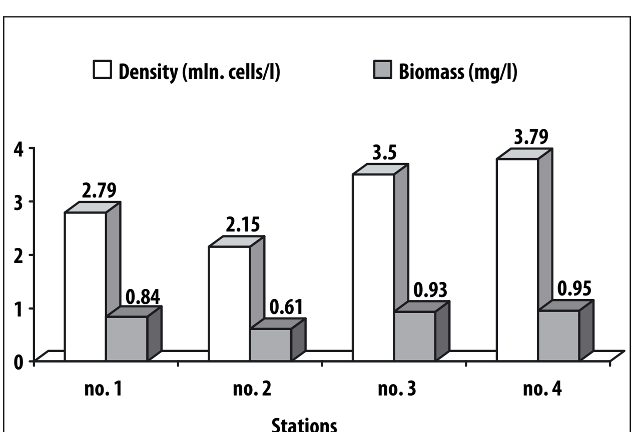

Fig. 3. Quantitative development of the phytoplankton in Kurdzhali Reservoir (July 2006).

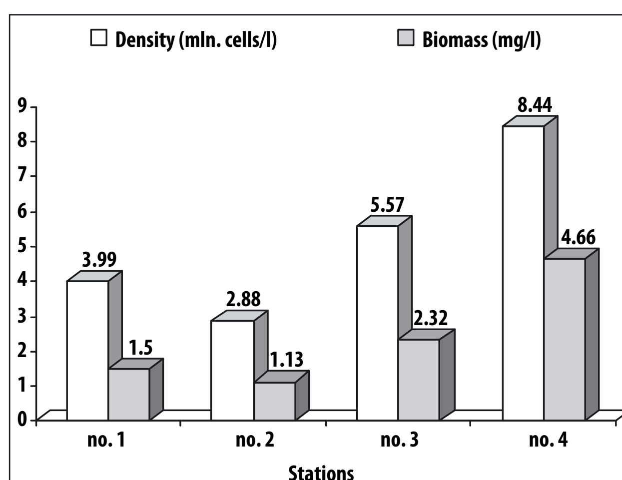

Fig. 4. Quantitative development of the phytoplankton in Kurdzhali Reservoir (September 2006).

Along with this, green algae developed most intensively near river Arda. At the river inlet (Station no. 4) they accounted for 52.5 % of the total density and for 66.7 % of the biomass. Dominant were the green algae *P. simplex* (3.32×10^6 cells/l) and *E. elegans* (0.49×10^6 cells/l). At the same station diatoms had a relatively poorer development: 25.1 % of the total density and 15.7 % of the biomass. They were represented by *F. crotonensis* (1.07×10^6 cells/l) and the minute *S. hantzschii* (1.04×10^6 cells/l).

The common tendency in the quantitative development of phytoplankton in Kurdzhali Reservoir in September was the lesser development of the blue-green algae, which preferred warm temperature and were replaced by diatoms (*F. crotonensis*, *S. hantzschii*) and the green algae (*P. simplex*, *E. elegans*).

Discussion

As a system for long-term monitoring of the conditions in lakes (reservoirs), ecological monitoring is primarily focused on their eutrophication (Trifonova & al. 1988). The changes connected with the process of eutrophication are first reflected in the community of autotrophic organisms, which are the first link in the nutrition chain. In lakes (reservoirs), phytoplankton is in principle the basic producer of organic matter and the chief factor for determining eutrophication is the increasing level of nutritious elements (Vollenweider & Kerekes 1980).

The processes of evolution towards rapid eutrophication are especially clear in artificial lakes – the reservoirs. The longevity of reservoirs is directly linked to the degree of anthropogenic interference into the life processes of the lake ecosystem by regulating water quantity and quality of the dammed water (Uzunov & Kovachev 2002).

The first and so far only complex hydrobiological research of Kurdzhali Reservoir deals with the basic hydrological, abiotic and biotic characteristics, as well as the Reservoir's trophic state (Traykov & Boyanovsky 2003; Traykov & al. 2003, 2005; Traykov 2005). As regards the phytoplankton, for the first time data were gathered about the species variety, quantitative development and factors influencing the phytoplankton succession in the various reservoir zones (Traykov 2005).

During our summer investigations of the phytoplankton in Kurdzhali Reservoir we have found a total of 55 species, belonging to six divisions: *Cyanoprokaryota* – 13, *Chlorophyta* – 23, *Zygnemaphyta* – 5, *Dinophyta* – 2, *Euglenophyta* – 3, and *Bacillariophyta* – 9 species. The divisions *Chlorophyta* (41.8 %), *Cyanoprokaryota* (23.6 %) and *Bacillariophyta* (16.4 %) had the highest relative abundance in the composition of the phytoplankton. Traykov (2005) lists 54 phytoplankton taxa from seven divisions and the most abundantly represented divisions are again *Chlorophyta* (46.3 %), *Bacillariophyta* (27.8 %) and *Cyanoprokaryota* (13.0 %). Further detailed comparisons of species variety are impossible, as the periods and sampling stations do not coincide.

Taxonomic composition of the algal species differed during the two months of research, and only 24 species (43.6 %) were common to both periods. The percentage of common species was lowest for the diatoms (33.3 %) and for the blue-green algae (38.5 %). Obviously, the lowering of water temperature in September has led to the replacement of warm-temperature preferring species by the colder-temperature preferring ones.

The species distribution across the Reservoir was heterogeneous. The stations at the tail end situated in the ecotone zone of river Arda – Kurdzhali Reservoir provided a considerably greater species diversity. This tendency was common for both months of research (Table 2) and coincides with the results of Traykov (2005). The increased content of nutrient matter brought in by the river, combined with suitable environmental conditions are the key factor for the increase of species variety. Such an increase of species variety in the zone between two different biotopes, known as 'boundary effect' (Odum 1975), has also been found in other Bulgarian reservoirs (Saiz 1987).

In terms of quantitative composition, the phytoplankton in summer was determined mostly by the blue-green, green and diatom algae, which is typical for mesotrophic lakes with oligotrophic characteristics (Trifonova 1986). In July, the total density was formed mostly by the blue-green algae. As regards the biomass, the dominant groups differed at the different stations, depending on the hydrochemical and hydrological conditions.

With the decrease of temperatures in September, the blue-green algae were replaced by the species with preferences for lower temperatures: diatoms and green algae. They formed the bulk both of density and of the biomass at all stations. Compared with July, the values for density and biomass were higher, which testifies to a more intensive algae development, especially at the stations near river Arda. These results correlate with the lesser water transparency in September (Table 1).

The average phytoplankton biomass for the researched period is 1.62 g/m^3, which corresponds to the boundary between oligo- and mesotrophic basin types (Trifonova 1986; Uzunov & Kovachev 2002). A common tendency for both months of research is the increase of phytoplankton biomass in the direction from the dam wall towards the ecotone zone of river Arda – Kurdzhali Reservoir, which is also an instance of the 'boundary effect' (Saiz 1987). Probable reasons for this may be the inflow of nutrient matter from river Arda and the lesser depth at Stations no. 3 and no. 4, which presumes faster regeneration of biogenic elements.

Our results represent a continuation of the research into phytoplankton variety, structure, distribution, and quantitative development in Kurdzhali Reservoir. They may serve as a basis for a database for continuous phytoplankton monitoring. Systematic long-term monitoring will be necessary to draw some more valid and better-grounded conclusions about the Reservoir's trophic state and the seasonal phytoplankton succession, considering the fact that phytoplankton is the most dynamic component of water ecosystems (Fedorov 1979).

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