Plankton community's production in the water area of the Volga-Kama Biosphere Reserve (Russia)

Nadezhda Stepanova[1*], *Tatiana* Kondratyeva[2], *Konstantin* Shevchuk[1], and *Oleg* Nikitin[3]

[1]Kazan Federal University, Kazan, 420008, Russia
[2]Department for Hydrometeorology and Environmental Monitoring of the Republic of Tatarstan, Kazan, 420021, Russia
[3]Ekoaudit LLC, Kazan, 420061, Russia

Abstract. The quantitative and production characteristics of planktonic community were assessed in the water area of the Volga Carbon Polygon (Saraly, Volzhsko-Kamsky State Nature Biosphere Reserve during the growing season of 2023. The Saralinsky section of Volga-Kama Reserve was characterized by high values of algae biomass, chlorophyll-*a* concentration and, accordingly, primary production of 110.6 ± 36.7 mgC/m^3 and characterized this area as hypereutrophic. Zooplankton production was 120.2±48.0 kcal/m^3/day or 12.0±4.8 mgC/m^3. The values of the *P/B* coefficient of the zooplankton community varied from 17 to 69, and are determined mainly by the production of small rotifers and cladocerans. These values indicate the eutrophic state of studied area.

1 Introduction

In recent years, there has been considerable focus on studying the distribution of energy flows within aquatic trophic webs to identify mechanisms contributing to ecosystem stability. Consistent with the trophic cascade concept, evaluating primary production in aquatic ecosystems remains pertinent.

The purpose of this work was to assess the quantitative and production characteristics of phytoplankton in the water area of the Volga Carbon Polygon (Saraly, Volzhsko-Kamsky State Nature Biosphere Reserve – VKBR).

2 Materials and methods

The reserve is located on the territory of the Republic of Tatarstan (Russia), and consists of two sections: Raifsky, with an area of 5921 hectares, located in the Zelenodolsk District of the republic, 25 km west of Kazan, and Saralinsky, with an area of 5456 hectares (including the protected water area), located in Laishevsky District, 60 km south of the capital of Tatarstan, on the shore of the Kuibyshev reservoir. In the relief of the Saralinsky site, which

* Corresponding author: nstepanova.kazan96@gmail.com

is a peninsula extended into the Kuibyshev Reservoir, three altitude levels are distinguished, corresponding to three Volga terraces of different ages. The lower (second floodplain) terrace, with absolute elevations of 50–60 m, is partially flooded by the reservoir, and is a series of islands rising above the water, usually 3–7 m; the highest heights – up to 20 m – are associated with sand dune areas. The middle (third floodplain) terrace, with absolute elevations of 75–90 m (20–35 m above the reservoir level), is characterized by a relatively level surface, with rare blue-shaped depressions and ravines; it accounts for the "mainland" part of the protected area. The upper (fourth floodplain) terrace, presented in the form of a large outlier with absolute heights of 120–144 m, has a dune topography. Channels and bays are spawning grounds for the main commercial fish species of the Kuibyshev Reservoir [1] (Figure 1).

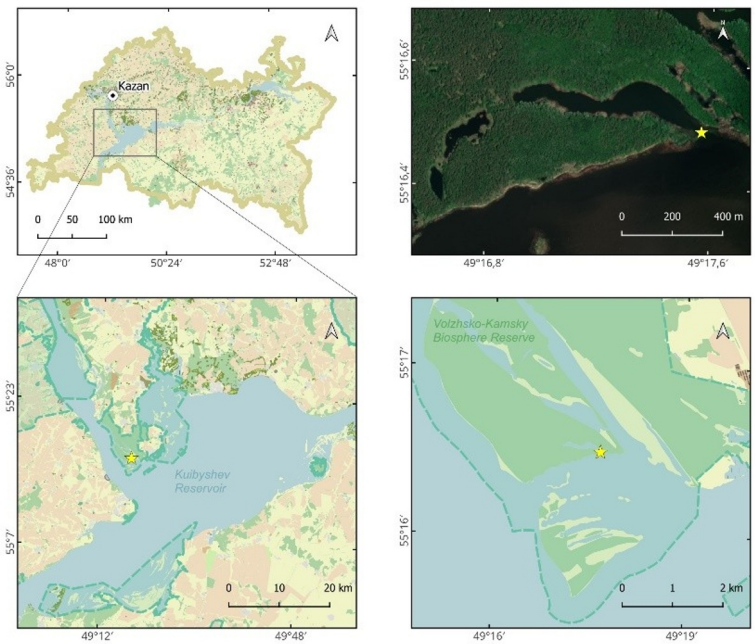

Fig. 1. The map of studied area (Saraly, Volzhsko-Kamsky State Nature Biosphere Reserve).

During the growing season of 2023, phytoplankton samples were taken in the water channel and bay in the Saralinsky section of the VKBR. The sample selection and hydrobiological treatment was carried out in accordance with the methodology [2]. Primary production was calculated by the "chlorophyll" method based on biomass values [3] and by the flask method [4].

3 Results and Discussion

In the Saralinsky section of the VKBR, 117 taxa of algae from 7 group were found: Cyanobacteria – 15, Bacillariophyceae – 37, Chlorophyta – 42, Euglenozoa – 11, Chrysophyceae – 5, Cryptophyta – 4, Dinophyceae – 3. The most taxa were found in the autumn (92), less in the summer (82).

The composition of phytoplankton in summer was dominated by green and blue-green algae – 42 and 34% of the total number, which reached 192.58 million cells/L, biomass - 65.41 mg/L. High biomass values were determined by the development of diatoms (81.5%)

and, in particular, *Stephanodiscus hantzschii* Grunow, 1880 (60.3%). In the autumn the number of algae decreased to 19.94 million cells/L, biomass – to 16.38 mg/L, but remaining at a high level. Blue-green algae dominated in the community (42% of the number) with a high proportion of diatoms and green algae (28 and 26% respectively) (Figure 2). The Milius Trophic Index values were 69.6, which corresponds to the eutrophic state. In general, this area is characterized by high values of phytoplankton biomass, chlorophyll-*a* (Chl-*a*) concentration and, accordingly, primary production (Table 1).

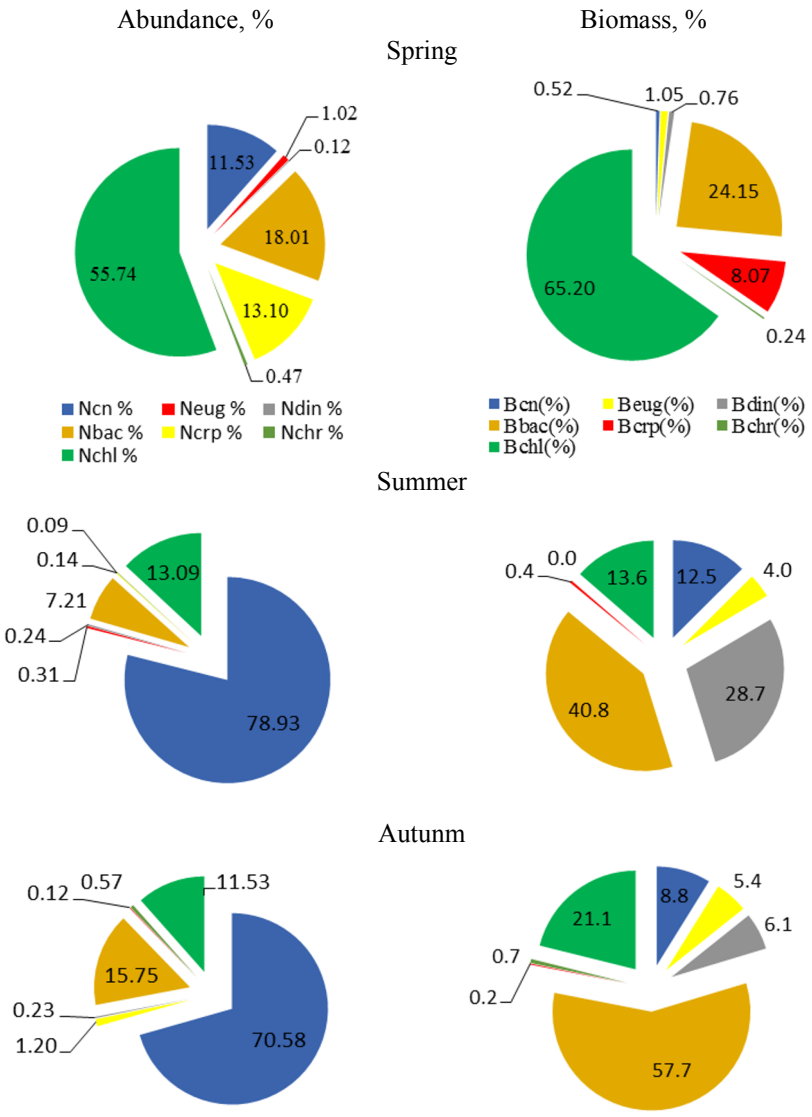

Fig. 2. The ratio of the relative abundance and biomass (%) of algae groups by season in the Saralinsky area (cn – blue-green, eug – Euglenoidea, din – Dinoflagellata, bac – Bacillariophyceae, chr – Chrysophyceae, crp – Cryptophyta, chl – Chlorophyta).

During the season the content of Chl-*a* varied from 7.42 to 163.54 mg/m^3. The minimum values occurred in May, the maximum – in June – the period with the maximum duration of daylight hours. Phytoplankton production calculated by biomass and by the

flask method varied throughout the season. Thus, phytoplankton production obtained by the calculation method was maximum in June, as well as the content of Chl-*a*. While net production reaches maximum values in September with a short photoperiod and predominance of blue-green algae in the phytoplankton, which make the main contribution to phytoplankton production. Average seasonal values of production are generally similar.

Table 1. Characteristics of phytoplankton.

Date	***B*** **(mg/m^3)**	**Chl-*a* (mg/m^3)**	**Production (mgC/m^3)**	****P*** **(mgC/m^3)**
May	7.49±2.27	18.74±5.66	69.35±20.96	80.0±49.8
June	20.23±15.06	50.58±37.65	187.14±139.32	69.3±41.3
August	12.62±5.07	31.55±12.68	116.74±49.91	125.9±31.1
September	7.49±1.34	18.72±3.36	69.28±12.44	176.0±29.8
**Average during the growing season	2.97-65.41 11.96±3.43	7.42-163.54 29.89±8.56	27.44-605.08 110.60±31.68	35.2-209.6 112.8±38.0

*Note: *P* – net production by flask method; **numerator – min-max, denominator – average ± standard deviation.

The highest phytoplankton productivity in the Kuibyshev Reservoir was observed in the extremely hot July of 2010. The absolute maximum Chl-*a* content reached 630 mg/m^3 in the surface layer. The intensity of photosynthesis of algae was 18.83 mg O_2/L/day [5]. In recent years (2015–2020), the content of Chl-*a* in the Kuibyshev reservoir was 9.2±1.0 μg/L, and the trophic status varies in different years from mesotrophic to moderately eutrophic and eutrophic [6].

Studies of production in the Saralinsky section carried out in 2003–2004 revealed that the intensity of photosynthesis in July 2003 was 0.36 mgO_2/L/day, in 2024 – 3.73 mgO_2/L/day. The level of production of summer phytoplankton in 2004 year, compared to 2003, was 10 times higher. The trophic status of this area, calculated based on gross production, was assessed in 2003 as eutrophic (Trophic State Index 61.2), in 2004 – as hypereutrophic [7]. The results of present study showed, that the Chl-*a* content was 6.8 times higher than the average for the reservoir, but lower than the results obtained for the hottest year of 2010. The trophic status of this area was assessed as hypereutrophic.

Thus, high rates of quantitative development of phytoplankton, as well as production characteristics (high values of the Chl-*a* content, phytoplankton production), indicate a high degree of eutrophication and potential for carbon sequestration of the Saralinsky section of the Volga-Kama State Natural Biosphere Reserve.

In the studied areas, 35 species were identified as part of zooplankton: Rotifera – 18, Cladocera – 11 and Copepoda – 6. The greatest species diversity was observed in the summer (32 species), the least – in autumn (2 types). Representatives of the Ponto-Caspian fauna were periodically encountered – the invaders *Heterocope caspia* Sars, 1893 and *H. appendiculata* Sars, 1863.

Quantitative parameters of zooplankton development varied widely. The number varied from 0.22 to 262.0 thousand ind./m^3, biomass – from 0.16 to 3147.8 mg/m^3. The bulk of the zooplankton were rotifers, which accounted for 91 and 81% of the abundance in spring and autumn, respectively. In August, copepods predominated in zooplankton (58% of the abundance) (Figure 3).

Previously, for the zooplankton of the Saralinsky section, from 43 [6] to 47 species [8] were indicated, with the dominant role of crustaceans, in particular the genus Bosmina, noted. The dominance of rotifers can be explained by the hydrological features of the Saralinsky section: shallow water and lack of current, which generally contributes to their development.

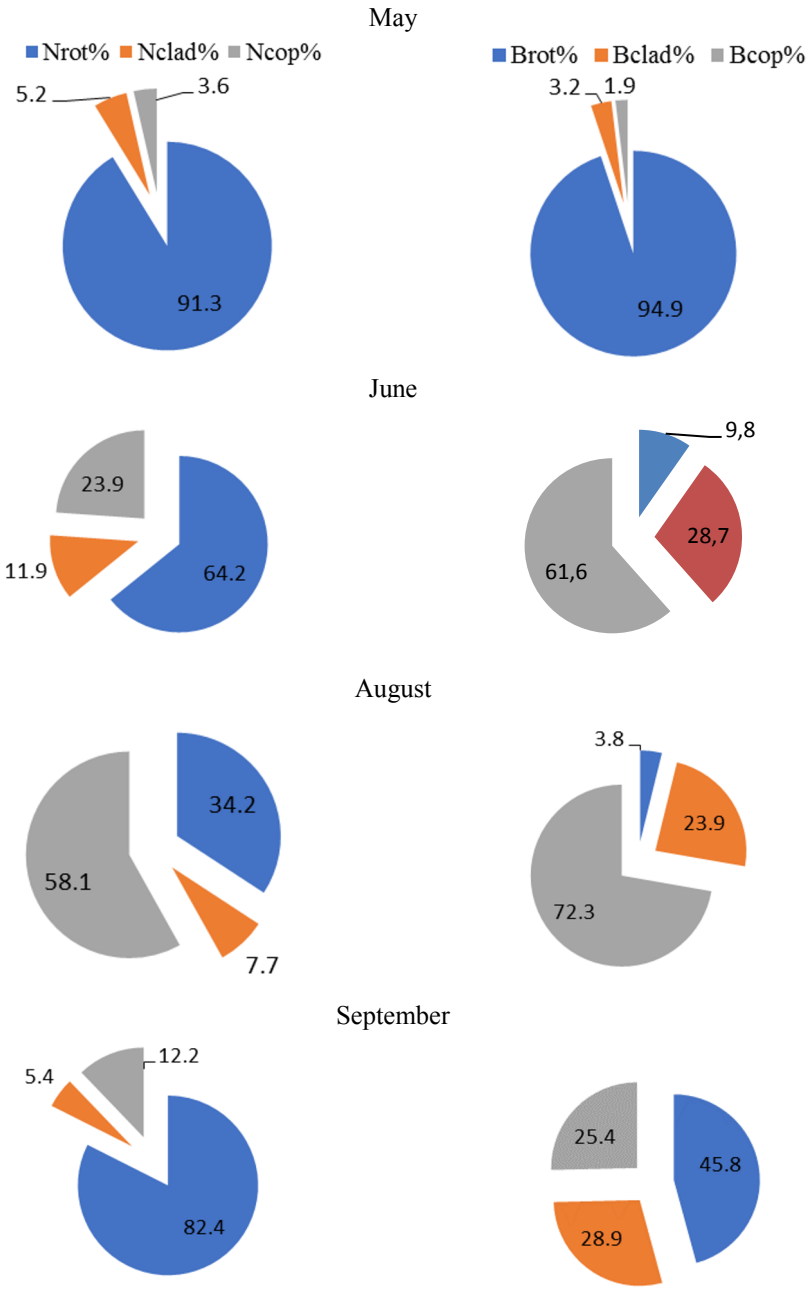

Fig. 3. The ratio of the relative abundance and biomass (%) of zooplankton groups by season (*N* – abundance, *B* – biomass, rot – rotifers, clad – cladoceran crustaceans, cop – copepods).

The maximum production values in the studied area were during the maximum period of plankton development – August (Table 2). The main contribution to the creation of secondary production in zooplankton was made by peaceful forms: peaceful forms of rotifers in the spring, cladoceran crustaceans in the summer, and peaceful forms of rotifers and copepods (mainly nauplial stages) crustaceans in autumn. These forms are the main

consumers of primary production (phytoplankton) and transfer the matter and energy from the lower to higher levels of the food chain - predators and then detritivores.

The turnover rate of *Bz* in eutrophic lakes is twice as high as in oligotrophic lakes and 20% higher than in mesotrophic lakes [9]. The values of the *P/B* coefficient in average 26±4, varying from 10 to 43, and are determined mainly by the production of small rotifers and cladocerans. These values indicate the eutrophic state of this area. Moreover, in conditions of eutrophication the increase of *P/B* coefficients is associated with a change in the structure of zooplankton. In particular, small R-strategist crustaceans and rotifers are dominated in the plankton community of eutrophic lakes, whose production capabilities are high. The *P/B* coefficient for peaceful rotifers is 2–10 times higher than for cladocerans, and 6–12 times higher than for copepods [10]. Low *Ppr*/*Pp* values indicate low predator pressure in the ecosystem, as is observed during eutrophication of lake ecosystems [11].

Table 2. Characteristics of zooplankton.

Date	B_Z*	*Pz***	R_Z	R_{pr}	P_p	P_{pr}	P_{pr}/P_p	*P/B*
May	817± 657	160±122 16±12	338± 262	158± 371	86± 71	516± 424	6.3± 9.3	19.7± 0.6
Jun	686± 294	169.1±66.4 17±7	332± 139	118± 56	128± 49	199± 92	1.5± 0.2	25± 5.2
Aug	2315± 2742	356±508 35±50	762± 1036	307± 278	264± 414	517± 465	3.7± 3.2	14.3± 4.4
Sep	2.7± 2.5	0.7±0.07 0.6±0.06	1.2± 1.1	0.4± 0.6	0.6± 0.4	0.6± 0.9	0.7± 0.8	36.8± 18.7

Note*: B_Z – biomass, g/m^3; *Pz* – numerator – production, kcal/m^3/day, denominator – mgC/m^3; P_p – production of peaceful forms (kcal/m^3/day); P_X – production of predators (kcal/m^3/day); R_{pr} – prey exchange rate (kcal/m^3/day); R_Z – exchange rate of all zooplankton (kcal/m^3/day).

4 Conclusion

In conclusion, the Saralinsky water section of Volga-Kama Reserve is characterized as hypereutrophic state by high values of phytoplankton biomass, chlorophyll-*a* concentration and, accordingly, primary production of 110.6±36.7 mgC/m^3. Zooplankton production was 120.2±48.0 kcal/m^3/day or 12.0±4.8 mgC/m^3. The values of the *P/B* coefficient of the zooplankton community in average 26±4, varying from 17 to 69, and are determined mainly by the production of small rotifers and cladocerans. These values indicate as well the eutrophic state of these areas.

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