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Article

Modern state of plankton and benthos of large fishery water bodies in Vologda region

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Abstract. The paper deals with monitoring results of phytoplankton, zooplankton and zoobenthos of the Sheksna reservoir, lakes Kubenskoye and Vozhe in Vologda Oblast in 2018–2022. The highest biomass of algae was recorded in lake Beloye (10.1 g/m^3). In other water bodies, the average biomass made up 6.3–7.3 g/m^3. Diatom and cyanobacteria dominated in phytoplankton: diatom number was maximum in the river part of the Sheksna Reservoir, while cyanobacteria – in lake Beloye. Highly abundant *Aphanizomenon flos-aquae* induced annual water bloom of lake Beloye. Density of zooplankton was the greatest in Vozhe (131 thous. ind./m^3, 3.5 g/m^3). Similar average biomass of zooplankton was noted in different parts of the Sheksna Reservoir (2.0 g/m^3). In lake Kubenskoye, biomass reached 0.9 g/m^3. Copepoda formed the base of zooplankton number and cladocera – of biomass. In contrast to lake Vozhe (2.6 g/m^2), zoobenthos in lake Kubenskoye was highly abundant (7.6 g/m^2). The average biomass of zoobenthos in the Sheksna Reservoir accounted for 4–5 g/m^2. The dominant complex of zoobenthos included oligochaeta *Limnodrilus hoffmeisteri*, *Tubifex newaensis*, *T. tubifex* in all water bodies; chironomid larvae *Chironomus* sp., *Procladius* sp. – in the open sites; chironomids *Endochironomus albipennis*, *Glyptotendipes gripekoveni*, *Cricotopus* gr. *sylvestris* – in thickets. Chironomidae dominated in the Sheksna Reservoir and lake Vozhe, oligochaeta – in lake Kubenskoye.

Keywords: phytoplankton, zooplankton, zoobenthos, Sheksna Reservoir, lake Kubenskoye, lake Vozhe

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Научная статья

Современное состояние планктона и бентоса крупных рыбохозяйственных водоемов Вологодской области

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Аннотация. Представлены результаты мониторинга фитопланктона, зоопланктона и зообентоса Шекснинского водохранилища, озер Кубенское и Воже Вологодской области в 2018–2022 гг. Наибольшая биомасса водорослей была характерна для озера Белое (10.1 г/м^3). В других водоемах средняя биомасса составляла 6.3–7.3 г/м^3. В фитопланктоне преобладали диатомовые водоросли и цианобактерии. Численность диатомовых водорослей была максимальна в речной части Шекснинского водохранилища, цианобактерий – в оз. Белом. В оз. Белое наблюдалось ежегодное «цветение» воды из-за высокой численности *Aphanizomenon flos-aquae*. Наибольшее обилие зоопланктона регистрировалось в оз. Воже (131 тыс. экз./м^3, 3.5 г/м^3). Средняя биомасса зоопланктона на всей акватории Шекснинского водохранилища была сходна (2.0 г/м^3), в оз. Кубенское равна всего 0.9 г/м^3. Основу численности зоопланктона составляли копеподы, биомассы – кладоцеры. Наибольшее обилие зообентоса было характерно для оз. Кубенское (7.6 г/м^2), наименьшее – для оз. Воже (2.6 г/м^2). Средняя биомасса зообентоса в Шекснинском водохранилище составила 4–5 г/м^2. В состав доминантов зообентоса во всех водоемах входили олигохеты *Limnodrilus hoffmeisteri*, *Tubifex newaensis*, *T. tubifex*, хирономиды родов *Chironomus, Procladius* в открытой части водоемов и хирономиды *Endochironomus albipennis*, *Glyptotendipes gripekoveni*, *Cricotopus* gr. *sylvestris* – в зарослях. Хирономиды доминировали в Шекснинском водохранилище и оз. Воже, олигохеты – в оз. Кубенское.

Ключевые слова: фитопланктон, зоопланктон, зообентос, Шекснинское водохранилище, озеро Кубенское, озеро Воже

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Introduction

Large reservoirs of Vologda Oblast – the Sheksna Reservoir (its lake and river parts), including lakes Kubenskoye and Vozhe, are of vital importance in terms of fishery. The studies of aquatic organisms in large reservoirs of this region began at the beginning of the 20th century (Arnold, 1925; Linko, 1903). The large-scale investigations of plankton and benthos of lakes and the Sheksna Reservoir (built in 1963) were carried out in 1950–1970 (Antropogennoe vliyanie..., 1981; Gidrobiologiya ozyor..., 1978; Guseva, 1959; Kiseleva, 1951; Kuzmin, 1966a, b, 1976; Luferova, 1966; Mordukhay-Boltovskoy, 1978; Mordukhay-Boltovskoy and Mitropolskiy, 1959; Nikolaev, 1977; Ozero Kubenskoye..., 1977a, b; Pidgaiko, 1969; Pikhtova, 1981; Poddubnaya, 1966; Rodionov et al., 1987; Sostoyanie rybnykh..., 1951; Strugach, 1951) and partially continued in the 1990s. (Sovremennoe sostoynie..., 2002).

For several decades, regular monitoring of plankton and benthos in the study water bodies was implemented by the Vologda Branch of VNIRO (Dumnich and Bolotova, 1996; Dumnich and Lobunicheva, 2016; Dumnich et al., 2021; Filonenko and Ivicheva, 2018; Ivicheva and Filonenko, 2018, 2023; Lobunicheva et al., 2022a; Makarenkova, 2015; Rastopchinova, 2004;). Since 2016, the monitoring of aquatic animals state in large water bodies has been carried out at a quarterly basis, including ice periods (Fig. 1). In conditions of natural and anthropogenic transformations of aquatic ecosystems, based on standard methods long-term observations of plankton and benthos make it possible to identify the changes occurring in their communities.

The purpose of this work is to assess the state of phytoplankton, zooplankton and zoobenthos of large fishery reservoirs in Vologda Oblast in summer of 2018–2022.

Material and methods

Characteristics of water bodies under study

In August–November 2018–2022, aquatic animals of the lake and river parts of the Sheksna reservoir, lakes Kubenskoye and Vozha were studied at the stations of the unified monitoring net (Fig. 1).

The Sheksna Reservoir is located in the western part of the Vologda Oblast. Created by damming the river Sheksna near the village Ust-Ugolskoye in June 1963, it is currently an integral part of the Volga-Baltic Waterway. The reservoir consists of three sections: the river Kovzhi (Belozerskaya), lake Beloye and the Sheksna flooded riverbed. The total length of the reservoir (from the Pakhomovsky to Sheksna hydroelectric complexes) is 262 km.

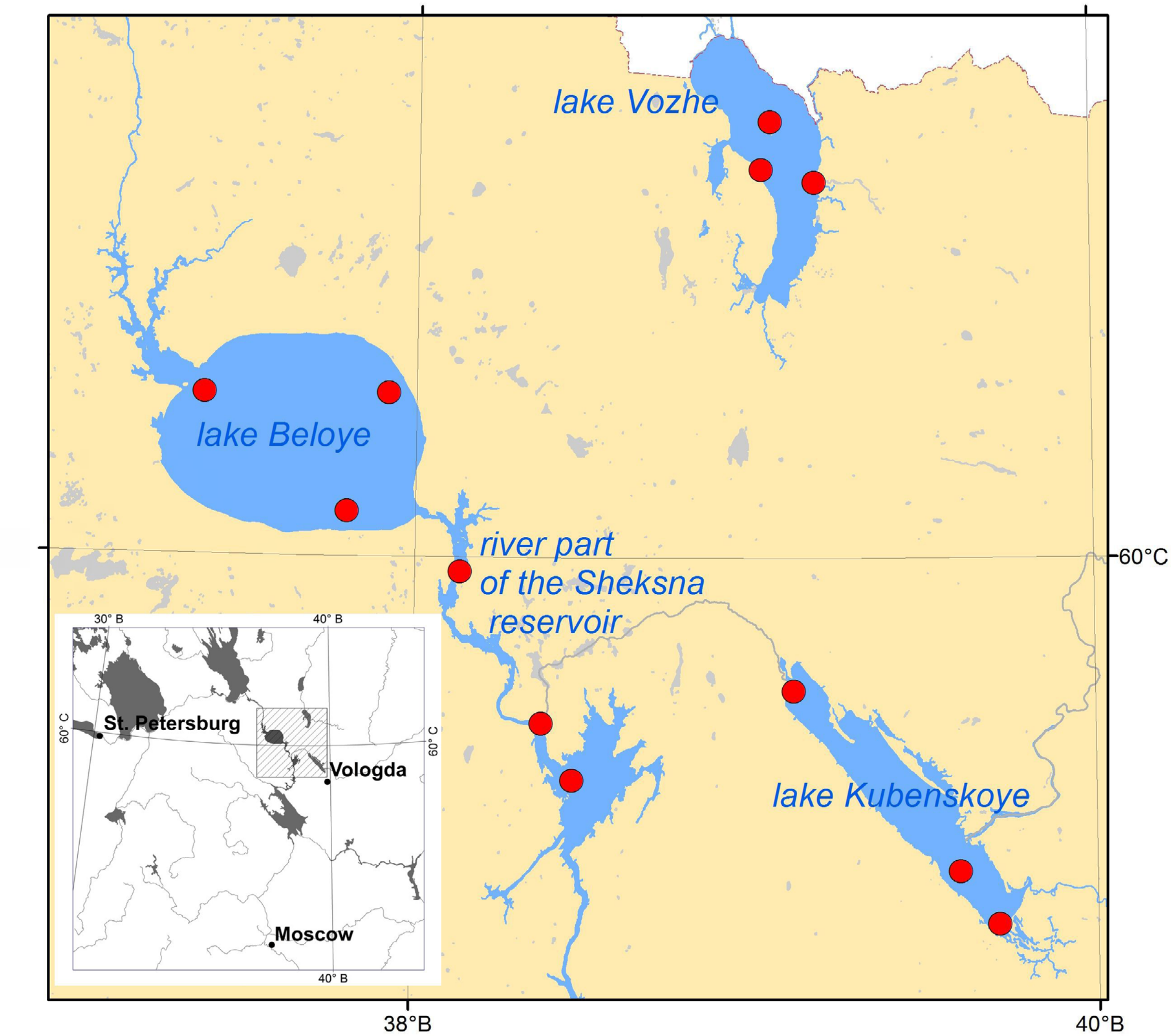

Fig. 1. Schematic map of location of sampling sites at large fishery reservoirs of Vologda oblast (2018–2022).

Lake Beloye is one of the largest fishery reservoirs in Vologda Oblast. The area of its water surface is 1284 km^2; the average depth – 4.1 m and the maximum – 6.3 m; the length of the lake – 46 km; the average width – 32 km (Litvinov, 2002). Rather constant water level in the lake favors to navigation. Lake Beloye is of a rounded shape without bays, with uniform distribution of depths, without a pronounced thicket zone. At a distance of up to 2 km from the shore line to its center, bottom sediments are represented by sands. In some places, there are pebbles and boulders. The central part of the lake is composed of clayer silts. Substrates with different proportions of silts occupy almost 90% of the lake area. The deepest sites of its river mouths are covered by substrates with large plant detritus. In the northwestern part, there are remains of flooded woody vegetation along the coast.

The river part of the Sheksna reservoir includes the Sheksna flooded channel from lake Beloye to the Sheksna hydroelectric complex. The reservoir is stretched from north to south for 120 km. After its filling, more than 530 km^2 of wetland forests (approximately 70% of which in the river part) were inundated (Ershova, 1968). A vast shoal was formed, i.e. the Sizma Razliv (Flood) occupying more than a half of the riverine part of the reservoir. Unlike lake Beloye, the river part of the Sheksna Reservoir has the deep-water zone (fairway) with depths of 20 m. At the same time, there are shallow water areas overgrown by macrophyte thickets in many parts of the reservoir. The average depth of the river part of the reservoir is 3.3 m (Litvinov, 2002). At the site from lake Beloye to Sizma Razliv, bottom sediments are represented by a combination of peat, eroded soils and silty sands. Because of shipping, in the bottleneck places of the Volga-Baltic Canal a permanent destruction of its banks brings to formation of the narrow sandy littoral with the precipice. The fairway is heavily silted and periodically dredged.

Lakes Kubenskoye and Vozhe belong to the White Sea basin. Lake Kubenskoye is located in the central part of the Vologda Oblast. The total area of the reservoir is 417 km^2 and its average depth – 2.5 m (Polyakov, 2002). From northwest to southeast, the lake has an elongated shape with a strongly indented coastline. The characteristic feature of its hydrological regime is significant water fluctuations. It should be noted that after the reconstruction of the North Dvina water system their amplitude decreased. The majority of the coastal shoals are formed of sands. However, along the coast, there are also rocky bottom sites. Bottom sediments of the central part are represented by gray silts. In clay places of the northeastern part of the water body, silts in various combinations with pebbles, shell rock and sand are noted. The mouth sections of inflowing rivers are characterized by silted sandy alluviums.

Lake Vozhe is located in the north of the Vologda Oblast; it is not connected by artificial waterways with other water bodies. In fact, this is currently the only large water body in Vologda Oblast with a natural hydrological regime, not regulated by hydraulic structures. Its average area of 418 km^2 varies significantly, depending on a season and water content. The long-term fluctuations of its water stages can reach 2 m; the average depth varies within 0.5–1.8 m (Tatarinova, 1979). The reservoir has the indented coastline, thick macrophyte thickets and swampy shores. The bottom sediments of the bays at the mouths of the inflowing rivers are represented by peat. Open areas of the littoral are composed of sands, in some places – of rocky ridges. The deep-water southern part of lake Vozhe is occupied by silts with sediments up to 2 m thick. The soils of the profundal in the northern part of the reservoir are predominantly sandy-clay with little silt.

Sample collection and processing

Phytoplankton sampling was implemented from the photic water layer with a Patalas bathometer (1 l) following the methodological recommendations (Metodika izucheniya..., 1975). The samples were fixed by Lugol solution with addition of formalin and then concentrated to 25 ml by settling. We quantitatively processed and identified algae using a Nageotte camera (0.01 ml) and a LOMO Mikmed 6 microscope. Biomass was calculated by the volumetric method; the specific algae weight was assumed to be 1 g/m^3 (Kuzmin, 1975). Species ≥ 10% of the total number and biomass of phytoplankton were classified as dominant. The taxonomic identification of algae was determined from “Opredelitel’ presnovodnykh vodorosley SSSR” and other literature (Komárek, 2013; Komárek and Anagnostidis, 1998, 2005; Komárek and Fott, 1983; Krammer and Lange-Bertalot, 1986, 1988, 1991a, b, etc.). The taxa representing more than 50% of all species found in the community were identified as dominants. The frequency of occurrence was defined from the ratio of the number of samples (where the given species was recorded) to the total number of samples.

Zooplankton samples were collected with a Judy net (inlet diameter of 18 cm, sieve with a mesh size of 75 μm) followed by fixation with a 4% formalin solution. Sampling was made in the littoral and pelagic zones of water bodies. In the littoral, the material was collected in macrophyte thickets occupying most of this area. In the pelagic zone of lakes Kubenskoye and Vozhe, plankton was taken from the sites with depths of 2–3 m; in lake Beloye – from 2–4 m, in the river part of the Sheksna reservoir – on the fairway.

Laboratory processing of zooplankton samples was carried out in accordance with the standard methods (Metodicheskie rekomendatsii..., 1982). The taxonomic identification of organisms was performed using the appropriate Key (Korovchinsky et al., 2021; Kutikova, 1970; Opredelitel’ zooplanktona..., 2010; etc.). The biomass of zooplankters was calculated by the formulas of the relationship between the mass and body length of organisms (Balushkina and Vinberg, 1979; Metodicheskie rekommendatsii..., 1982; Ruttner-Kolisko, 1977). In addition, the complexes of dominant species (with a relative abundance of more than 5%) were identified for rotifers and crustaceans. The total number (thous. ind./m^3) and biomass (g/m^3) of zooplankton, as well as individual taxonomic groups, were calculated.

Collection of zoobenthos on silts was carried out by the Peterson or Van Veen grabs with a capture area of 0.025 m^2 (once) and on dense substrates – with a GR-91 rod grab with a bucket area of 0.007 m^2 (three times). Sampling was made in the profundal and littoral zones (along the water edge and at depths less than 1 m), in bays and in the mouth of tributaries (the rivers Kovzha, Vozhega, Bolshaya

Elma, and Koy). Samples were washed using a sieve with a mesh size of 250 μm, fixed with a 40% formalin solution, and studied in the laboratory. Bottom animals were identified to the lowest taxonomic levels possible (Opredelitel' zooplanktona..., 2016; Opredelitel' presnovodnykh..., 1977, 1999, 2001).

The average abundance and biomass of phytoplankton and zooplankton were analyzed based on material collected in August, zoobenthos – in August–November 2018–2022 A total of 488 hydrobiological samples were taken and processed (phytoplankton – 98, zooplankton – 144, zoobenthos – 246).

Mathematical data processing, including the estimate of the coefficient of variation (CV) and the error of mean values, were carried out by the standard statistical methods (Ivanter and Korosov, 2010) using MS Excel 2016 software (note: built-in functions and macros were specially created for calculating individual parameters). The classification of reservoirs by the level of a food base was made in accordance with M.L. Pidgaiko et al. (1968) and I.S. Trifonova (1990). The ArcGis 10 package served as the main tool in analyzing spatial data.

Results

The lake part of the Sheksna reservoir (Lake Beloye)

Phytoplankton

The phytoplankton composition of lake Beloye mainly consisted of cyanobacteria, diatoms and green algae. Other divisions were represented to a lesser extent. The genera *Aulacoseira* Thw., *Fragilaria* Lyngb., *Navicula* Bory (Bacillariophyta), *Monoraphidium* Kom.-Legn., *Scenedesmus* Meyen (Chlorophyta), and *Aphanocapsa* Näg. (Cyanophyta) stood out for species number and intraspecies taxa. Chlorococcales, Chroococcales, and Raphales dominated. *Aulacoseira islandica* (O. Müll.) Sim. (79%), *Asterionella formosa* Hass. (79%), *Aphanizomenon flos-aquae* Ralfs ex Born. & Flah. (67%), *Actinocyclus normanii* (Greg. ex Grev.) Hust. (58%), *Komma caudata* (Geitler) D.R.A. Hill (50%), *Stephanodiscus* sp. (50%), *Aulacoseira ambigua* (Grun.) Sim. (46%), *Aulacoseira* sp. (42%), *Cryptomonas marssonii* Skuja (42%) were most common.

The average biomass of summer phytoplankton in lake Beloye reached 10.1 ± 2.37 g/m^3 largely due to diatoms (6–99%) and cyanobacteria (1–87%), which also formed the bulk of cells (1–93% and 4–98%, respectively). Phytoplankton number was on average 97.5 ± 23.71 mln. cells/l (Table 1). Maximum abundance of phytoplankton was recorded mainly due to intensive development of *Aulacoseira islandica* and *Aphanizomenon flos-aquae* in 2021 (9.3 ± 1.50 g/m^3 and 116.5 ± 29.66 mln. cells/l) and 2022 (11.8 ± 1.94 g/m^3 and 93.5 ± 12.99 mln. cells/l). In 2018–2020, algae biomass was within 4.6–5.4 g/m^3, its number – 23.2–55.0 mln. cells/l. Among diatoms, *Actinocyclus normanii, Asterionella formosa, Aulacoseira ambigua, A. granulata* (Ehr.) Sim., *A. islandica, Aulacoseira* sp., *Fragilaria crotonensis* Kitt., *Stephanodiscus* sp., *Surirella* sp. dominated in plankton. Among cyanobacteria, *Aphanizomenon flos-aquae, Aphanocapsa delicatissima* W. & G.S. West, *A. holsatica* (Lemm.) Cronb. & Kom., *Dolichospermum* sp., *Microcystis aeruginosa (*Kütz.) Kütz., *M. wesenbergii* (Kom.) Kom. ex Kom., *Planktolyngbya limnetica* (Lemm.) Kom.-Legn. & Cronb., *Snowella lacustris* (Chod.) Kom. & Hind., *Woronichinia compacta* (Lemm.) Kom. & Hind. prevailed in number and biomass. Dominant complexes also included *Ceratium hirundinella* (O.F. Müll.) Duj., *Dictyosphaerium ehrenbergianum* Näg., *Pseudopediastrum boryanum* (Turp.) Hegew., *Pediastrum duplex* Meyen, *Staurastrum* sp.

Zooplankton

Zooplankton of the lake part of the Sheksna Reservoir in 2018–2022 was represented by species widespread in the region. In 2020, invasive North American rotifer *Kellicottia bostoniensis* (Rousselet, 1908) was again noted in the water body. It was first detected there in 2005 (Lazareva and Zhdanova, 2014) and one specimen was found in March 2017 (Lobunicheva et al., 2022b).

The average number and biomass of zooplankton in the reservoir during the study period were 65.2 ± 8.29 thous. ind./m^3 and 2.1 ± 0.30 g/m^3, respectively (Table 2). Zooplankton abundance varied significantly over the years. CV for zooplankton number was 58%, for biomass – 49%. The maximum number and biomass of zooplankton (46.6 ± 3.04 thous. ind./m^3 and 3.7 ± 0.74 g/m^3) were recorded in August 2022. In 2018–2021, CV of the total number and biomass made up 49 and 16%, respectively. The average number of summer zooplankton was within 70.8 ± 10.47 thous. ind./m^3 and biomass – 1.5 ± 0.23 g/m^3.

Copepods (51–66%) formed the basis of zooplankton number in lake Beloye every summer. Among dominants were *Mesocyclops leuckarti* (Claus, 1857), *Eudiaptomus gracilis* (G.O. Sars, 1863). In

Table 1. Average number and biomass of phytoplankton in large fishery reservoirs of Vologda oblast (August 2018–2022).

Division	Water body			
	Sheksna Reservoir		Lake Kubenskoye	Lake Vozhe
	River part	Lake part (Lake Beloye)		
	Abundance, mln. cells/l			
Bacillariophyta	14.21 ± 2.932	10.23 ± 1.812	19.83 ± 5.392	28.28 ± 8.206
Cyanophyta	16.22 ± 3.729	83.32 ± 23.678	59.13 ± 27.296	124.58 ± 28.259
Chlorophyta	3.20 ± 1.239	1.44 ± 0.336	11.63 ± 5.980	15.11 ± 3.929
Chrysophyta	0.12 ± 0.044	0.35 ± 0.108	1.05 ± 0.446	1.96 ± 0.521
Xanthophyta	0.03 ± 0.019	0.01 ± 0.007	0.03 ± 0.016	0.19 ± 0.042
Cryptophyta	3.40 ± 0.976	2.05 ± 0.617	3.59 ± 1.786	4.35 ± 1.188
Euglenophyta	0.27 ± 0.092	0.08 ± 0.037	1.53 ± 0.691	0.45 ± 0.107
Dinophyta	0.05 ± 0.018	0.02 ± 0.008	0.23 ± 0.123	0.42 ± 0.098
Total	**37.50 ± 7.889**	**97.50 ± 23.706**	**97.02 ± 39.790**	**175.34 ± 40.662**
	Biomass, g/m^3			
Bacillariophyta	5.04 ± 1.114	4.82 ± 0.792	4.32 ± 1.130	4.42 ± 0.841
Cyanophyta	0.53 ± 0.103	4.51 ± 1.825	2.17 ± 1.086	1.35 ± 0.312
Chlorophyta	0.26 ± 0.045	0.29 ± 0.065	0.32 ± 0.114	0.74 ± 0.167
Chrysophyta	0.07 ± 0.035	0.05 ± 0.020	0.07 ± 0.024	0.18 ± 0.047
Xanthophyta	0.01 ± 0.007	< 0.01 ± 0.001	0.01 ± 0.002	0.03 ± 0.009
Cryptophyta	0.23 ± 0.039	034 ± 0.107	0.25 ± 0.077	0.18 ± 0.028
Euglenophyta	0.07 ± 0.023	0.05 ± 0.019	0.15 ± 0.062	0.08 ± 0.024
Dinophyta	0.09 ± 0.042	0.03 ± 0.009	0.02 ± 0.006	0.07 ± 0.017
Total	**6.30 ± 1.133**	**10.09 ± 2.369**	**7.31 ± 2.463**	**7.05 ± 1.320**

August, the share of *Cyclops* nauplii (up to 39%) in the community was high. Maximum biomass was characteristic of cladocerans (45–85% of the total biomass). Every year, *Daphnia galeata* Sars, 1864 dominated in the lake at the end of summer. In some years, a relatively high number of *Daphnia cristata* Sars, 1862, *Chydorus sphaericus* (O.F. Müller, 1776), *Limnosida frontosa* Sars, 1862 was recorded during this period.

Rotifers were abundant only in some years due to local mass development of *Kellicottia longispina* (Kellicott, 1879) and *Conochilus hippocrepis* (Schrank, 1803) (Lobunicheva et al., 2022a). In 2018–2022, their share in the total number did not exceed 20%. *K. longispina and Euchlanis dilatata* Ehrenberg, 1832 prevailed. Starting from 2019, a low abundance of rotifers of the genus *Polyarthra (P. major* Burckhardt, 1900, *P. vulgaris* Carlin, 1943, *P. euryptera* Wierzejski, 1891) was recorded in August.

Abundance of cladocerans and rotifers varied significantly over the years (CV 61–95%). Cladocera characterized by higher number and biomass was responsible for variations in total abundance of zooplankton.

Zoobenthos

In 2018–2022, zoobenthos abundance was similar throughout lake Beloye. The average number and biomass of zoobenthos in the lake during the study period made up 908 ± 114.0 ind./m^2 and 4.0 ± 0.55 g/m^2, respectively (Table 3a). The zoobenthos of the profundal was most diverse. Here, bottom

Table 2. Average number (N, th. ind./m^3) and biomass (B, g/m^3) of zooplankton of large fishery reservoirs of Vologda oblast (August 2018–2022).

Biotope	A group of organisms						Всего	
	Cladocera		Copepoda		Rotifera			
	N	B	N	B	N	B	N	B
Sheksna Reservoir, lake part (Lake Beloye)								
Mean	17.2 ± 3.16	1.4 ± 0.26	37.3 ± 4.47	0.6 ± 0.07	10.7 ± 1.81	0.1 ± 0.02	65.2 ± 8.29	2.1 ± 0.30
Sheksna Reservoir, river part								
Pelagial	48.2 ± 13.4	1.4 ± 0.34	59.5 ± 8.39	0.7 ± 0.13	9.4 ± 2.45	0.5 ± 0.39	117.1 ± 20.93	2.6 ± 0.75
Littoral	33.2 ± 11.83	1.0 ± 0.36	39.6 ± 9.75	0.5 ± 0.14	4.5 ± 1.53	0.1 ± 0.04	77.3 ± 18.57	1.6 ± 0.45
Mean	42.0 ± 9.19	1.3 ± 0.25	50.9 ± 6.51	0.6 ± 0.09	6.7 ± 1.53	0.1 ± 0.03	99.6 ± 11.45	2.0 ± 0.28
Lake Kubenskoye								
Pelagial	10.7 ± 2.85	0.4 ± 0.11	72.5 ± 8.99	0.4 ± 0.05	13.6 ± 4.00	0.1 ± 0.05	96.8 ± 11.68	0.9 ± 0.14
Littoral	6.4 ± 2.57	0.4 ± 0.19	64.9 ± 18.00	0.4 ± 0.15	7.5 ± 4.07	< 0.1 ± 0.02	78.7 ± 20.27	0.9 ± 0.31
Mean	9.8 ± 2.33	0.4 ± 0.09	70.9 ± 7.92	0.4 ± 0.05	12.2 ± 3.22	0.1 ± 0.04	91.6 ± 10.09	0.9 ± 0.13
Lake Vozhe								
Pelagial	51.2 ± 6.98	1.7 ± 0.27	90.7 ± 10.67	0.7 ± 0.09	22.4 ± 3.54	1.2 ± 0.43	164.3 ± 17.78	3.6 ± 0.58
Littoral	42.5 ± 6.08	2.6 ± 0.54	44.1 ± 6.31	0.4 ± 0.09	15.5 ± 5.46	0.5 ± 0.23	98.0 ± 11.53	3.4 ± 0.60
Mean	46.8 ± 4.62	2.1 ± 0.30	67.8 ± 6.93	0.6 ± 0.06	19.3 ± 3.14	0.9 ± 0.26	131.1 ± 11.39	3.5 ± 0.41

substrates were composed of silts inhabited by dominant representatives of zoobenthos, i.e. large chironomids of the genera *Chironomus, Procladius, Polypedillum* and tubificids *Limnodrilus hoffmeisteri* Claparède, 1862, *Tubifex newaensis* (Michaelsen, 1903), *T. tubifex* (Müller, 1774).

The highest number and biomass of zoobenthos in lake Beloye were recorded in 2018 (3010 ± 220.5 ind./m^2 and 7.8 ± 0.52 g/m^2, respectively). In 2019–2022, the number and biomass of zoobenthos of the lake were low. The decreased average values of these indicators were mainly associated with a reduced number of chironomids in the reservoir. Dominant representatives of this group involved *Chironomus* sp. with relatively large larvae. Spatial distribution of *Chironomus* sp. in the reservoir was extremely uneven. The abundance of chironomids in a particular growing season strongly correlated with air temperature and wind regime during the period of adult swarming (Motyl' *Chironomus...,* 1983; Shilova, 1976). May-June of 2018–2022 in the Vologda Oblast was distinguished by anomalously high and low air temperatures (Doklad ob osobennostyakh..., 2023). Thermal fluctuations brought to reduction in the number and biomass of chironomids in the lake.

The river part of the Sheksna reservoir

Phytoplankton

The composition of phytoplankton in the river part of the Sheksna Reservoir in summer was formed mainly of green and diatom algae, and to a lesser extent – of representatives of other divisions and cyanobacteria. The genera of green *Monoraphidium, Oocystis* A. Br., *Pediastrum* Meyen, *Scenedesmus,* diatoms – *Aulacoseira, Fragilaria,* cyanobacteria – *Dolichospermum* (Ralfs ex Born. & Flah.) Wacklin, Hoffmann & Kom., golden – *Dinobryon* Err., and cryptophyte algae – *Cryptomonas* Ehr. stood out for species number and intraspecific taxa. The leading divisions in phytoplankton included Araphales, Chlorococcales, Melosirales, and Raphales. The most common species in the community were *Aulacoseira islandica* (62%), *Asterionella formosa* (58%), *Aphanizomenon flos-aquae* (58%), *Aphanocapsa incerta* (Lemm.) Cronb. & Kom. (54%), *Monoraphidium contortum* (Thur.) Kom.-Legn. (54%), *Actinocyclus normanii* (50%).

In summer, the average long-term phytoplankton biomass reached 6.3 ± 1.13 g/m^3 (Table 1) mostly due to diatoms *Aulacoseira ambigua, A. islandica, Aulacoseira* sp., *Actinocyclus normanii, Gyrosigma attenuatum* (Kütz.) Rabenh., *Melosira varians* Ag., *Stephanodiscus* sp. (50–93%). On average, the highest biomass indicators were observed in 2019 (12.3 ± 2.60 g/m^3) because of intensive development of diatoms, in particular, of *Aulacoseira and Asterionella formosa* species. High algae biomass was also noted in 2022 (8.2 ± 2.18 g/m^3) at high concentrations of both diatoms (*Asterionella formosa, Aulacoseira islandica*) and cyanobacteria (*Aphanizomenon flos-aquae, Aphanocapsa delicatissima, A. holsatica, Microcystis aeruginosa, M. wesenbergii, Planktolyngbya limnetica, Pseudanabaena limnetica* (Lemm.) Kom.). The average abundance of algae varied as 7.8 ± 4.03 and 77.5 ± 8.89 mln. cells/l in 2020 and 2022, respectively. The long-term average number accounted for 37.5 ± 7.89 mln. cells/l. The basis of phytoplankton number was cyanobacteria (up to 76% of the total number), among which *Aphanizomenon flos-aquae, Aphanocapsa holsatica, A. delicatissima, Dolichospermum* sp., *Oscillatoria* sp., *Phormidium* sp., *Microcystis aeruginosa, Planktolyngbya limnetica, Pseudanabaena limnetica* prevailed. Diatoms also dominated (12–65%). The largest number of cyanobacteria was noted in 2021–2022 (34.2 ± 6.29 and 21.0 ± 3.19 mln. cells/l, respectively).

Zooplankton

In summer, zooplankton in deep-water and coastal areas of the river part of the Sheksna Reservoir differed. The peak of zooplankton abundance was usually recorded in the fairway of the reservoir (Table 2). Only in August 2018, its number and biomass in macrophyte thickets were higher due to relatively high density of phytophilic *Sida crystallina* (O.F. Müller, 1776) or *Mesocyclops leuckarti*. At some stations, abundant *S. crystallina* contributed to widely varying over the years the average number, and, especially, zooplankton biomass. Except for this species, CV for zooplankton abundance in the river part of the Sheksna Reservoir in August was 40% and biomass – 34%.

In August of 2018–2022, the average number of zooplankton in the reservoir made up 99.6 ± 11.45 thous. ind./m^3 and biomass – 2.0 ± 0.28 g/m^3. The highest and comparable number and biomass of zooplankton were recorded in the years 2018, 2021 and 2022.

The dominant group of zooplankters in the reservoir were crustaceans. In different years, their community was mainly formed by cladocerans or copepods. Cladocerans produced maximum biomass.

For the analyzed five-year period, the average biomass of Cladocera and copepods in August was comparable only for 2019. In 2021, rather high biomass (up to 6.3 g/m^3) of rotifer *Asplanchna priodonta* Gosse, 1850 was recorded in some stations.

The composition of the dominant zooplankton complex in the reservoir remained the same. *Chydorus sphaericus, Mesocyclops leuckarti, Eudiaptomus gracilis, Kellicottia longispina* prevailed in the reservoir every year. Also, among the dominants were *Bosmina coregoni* Baird, 1857 and species of the genus *Polyarthra*. In some years, a high number of *Diaphanosoma brachyurum* (Liévin, 1848), *Daphnia cristata, Asplanchna priodonta, Keratella cochlearis* (Gosse, 1851), *Euchlanis dilatata* was noted.

Zoobenthos

The greatest contribution to the number and biomass of zoobenthos in the riverine part of the Sheksna Reservoir was made by the inhabitants of silts concentrated along the fairway and in the old riverbeds existed before the reservoir construction. The number of organisms in these parts of the reservoir was most stable. Large chironomids of the genera *Chironomus* and *Procladius*, including *tubificids Limnodrilus hoffmeisteri, Tubifex newaensis, T. tubifex* predominated. In 2018–2022, the average number of zoobenthos in this part of the reservoir reached 1693 ± 346.9 ind./m^2, biomass – 4.9 ± 0.91 g/m^2 (Table 3a). The number was lower than the long-term average, while biomass – close to the latter one (Filonenko et al., 2021). In 2021, zoobenthos number was particularly low in the reservoir. In 2022, this indicator was within the average long-term values.

We recorded maximal number and biomass of zoobenthos in the bays and in the littoral of the river part of the Sheksna Reservoir. On rocky coastal sites and in vegetation of shallows, abundance of amphipod *Gmelinoides fasciatus* (Stebbing, 1899) was the highest. The number of this species in the water body could reach 7 thous. ind./m^2, biomass – 21 g/m^2.

Lake Kubenskoye

Phytoplankton

Diatoms and to a lesser extent – green and other divisions of algae, formed the basis of phytoplankton of lake Kubenskoye. The leading genera among greens were *Monoraphidium, Pediastrum, Scenedesmus*, diatoms – *Euglena* Ehr., euglenidae – *Aulacoseira, Synedra* Ehr, golden algae – *Dinobryon*, and cyanobacteria – *Dolichospermum*. They accounted for more than half of all species found in the community. In phytoplankton, Araphales, Chlorococcales, Euglenales, and Raphales were in the lead. By frequency of occurrence, *Aulacoseira* sp. (100%), *A. ambigua* (92%), *Asterionella formosa* (80%), *Aulacoseira granulata* (62%), *Dolichospermum* sp. (62%), *Monoraphidium contortum* (62%), *Aphanizomenon* sp. (50%), *Pediastrum duplex* (50%), *Planktolyngbya limnetica* (50%), *Pseudanabaena limnetica* (50%) predominated.

Summer phytoplankton of lake Kubenskoye was characterized by the average biomass of 7.4 ± 2.46 g/m^3 and number of 96.9 ± 39.79 mln. cells/l (Table 1); diatoms accounted for 49–95% of biomass and 5–96% of population, while cyanobacteria – around 1–50% and 2–88%, respectively. The average biomass of algae varied from 1.6 ± 0.56 (2018) to 21.0 ± 7.85 g/m^3 (2022). In 2018, cyanobacteria reached 86% of the total number of phytoplankton, among which *Aphanocapsa delicatissima, A. holsatica;* species of the genus *Dolichospermum, Planktolyngbya limnetica,* and *Pseudanabaena limnetica* dominated. The total number was 39.8 ± 19.58 mln. cells/l. The largest contribution to biomass was made by diatoms (up to 51%), in particular, threadworms *Melosira varians, Aulacoseira ambigua, A. islandica, Aulacoseira* sp. In 2022, when phytoplankton number showed its maximum (324.3 ± 109.35 mln. cells/l), cyanobacteria, green algae, and diatoms dominated in the community. The complex of cyanobacteria was predominantly formed by non-heterocyst filamentous alga *Oscillatoriales (Planktolyngbya limnetica* and *Pseudanabaena limnetica* dominated). Green algae were represented by Chlorococcal species. In particular, *Ankistrodesmus falcatus* (Corda) Ralfs, *Pediastrum duplex, Scenedesmus quadricauda* (Turp.) Bréb. Among diatoms, *Aulacoseira* sp., *Asterionella formosa, Stephanodiscus binderanus* (Kütz.) Krieg prevailed. In 2019–2021, algae biomass was 3.6–4.5 g/m^3; its number – 5.0–99.6 mln. cells/l. In different years, dominant groups also included *Ceratium hirundinella, Cymatopleura nobilis* Hantzsch, *Dolichospermum* sp., *Pediastrum angulosum* Ehr. ex Menegh., *Ulnaria acus* (Kütz.) Aboal.

Zooplankton

In August of 2018–2022, the average number of zooplankters in lake Kubenskoye made up 91.6 ± 10.09 thous. ind./m^3 with biomass of 0.9 ± 0.13 g/m^3 (Table 2). The structure and abundance of zooplankton were similar throughout the water area.

Zooplankton of the lake demonstrated interannual fluctuations in its number and biomass. In 2018–2021, CV of the total number and biomass was 55 and 60%, respectively. Abundance of cladocerans varied greatly during the study period (106%). In different years, the average number and biomass of rotifers also differed significantly (124 and 128%, respectively). In August of 2021–2022, rotifers *Euchlanis dilatata or Asplanchna priodonta* were highly abundant. Rather high average zooplankton biomass was recorded in August 2018 (1.5 ± 0.40 g/m^3) due to *Daphnia cucullata* Sars, 1862 and numerous *Sida crystallina* in different parts of the lake. Extremely low number and biomass of zooplankton were noted in August 2019 (19.8 ± 2.36 thous. ind./m^3 and 0.1 ± 0.02 g/m^3, respectively).

In lake Kubenskoye, copepods were the basis of zooplankton number. The relative biomass of copepods and cladocera were similar. In different years, the composition of dominants included up to six species. In late summer, *Thermocyclops oithonoides* (G.O. Sars 1863) and rotifers of the genus *Polyarthra (P. euryptera, P. vulgaris, P. dolichoptera* Idelson, 1925) dominated yearly. In some years, among cladocera, *Daphnia cucullata* or *Diaphanosoma brachyurum* while among copepods – *Mesocyclops leuckarti* prevailed. The composition of the dominant rotifers was most diverse. For instance, in addition to the mentioned above, they included *Kellicottia longispina, Asplanchna priodonta, Keratella cochlearis, Euchlanis dilatata*.

Zoobenthos

In lake Kubenskoye, the inhabitants of silts in the deep-water area and the mouth areas of inflowing rivers provided the largest contribution to the number and biomass of zoobenthos. Chironomids of the genus *Chironomus* dominated in silts, while oligochaetes *Limnodrilus hoffmeisteri, Tubifex newaensis,* and *T. tubifex* – in sites of the confluence of the rivers. In 2018–2022, the average number of zoobenthos in the reservoir was 1442 ± 217.6 ind./m^2, biomass – 7.6 ± 1.20 g/m^2 (Table 3b). The obtained values of biomass were within the average long-term ones despite the decreased number of bottom organisms (Filonenko, 2018). The maximum quantitative characteristics of zoobenthos in the study period were noted in 2019.

High number and biomass of zoobenthos in the littoral of lake Kubenskoye (2300 ± 306.0 ind./m^2 and 9.7 ± 1.47 g/m^2, respectively) were caused by chironomid larvae and appeared in 2014 amphipod *Gmelinoides fasciatus*, which developed as on the open bottom areas as among meager thickets of submerged aquatic vegetation. A considerable biomass of benthic animals was also observed on silts of the deep-water zone (7.7 ± 1.20 g/m^2) primarily due to *Chironomus* sp. development.

Lake Vozhe

Phytoplankton

Phytoplankton of lake Vozhe was represented mainly by diatoms, green algae and cyanobacteria. Other divisions of algae were less diverse and, generally, not abundant in plankton. High species richness was typical of the genera of diatoms *Fragilaria, Navicula, Nitzschia* Hass., *Surirella* Turp., *Synedra;* green – *Pediastrum, Scenedesmus,* cryptophytes *Cryptomonas;* cyanobacteria *Aphanocapsa, Dolichospermum*. Araphales, Chlorococcales, Chroococcales and Raphales dominated. By frequency of occurrence in the community, the species *Fragilaria* spp. (100%), *Aulacoseira ambigua* (85%), *Ulnaria ulna* (Nitzsch) Compère (85%), *Aulacoseira* sp. (62%), *Planktolyngbya contorta* (Lemm.) Anagn. & Kom. (62%), *Tabellaria fenestrata* (Lyngb.) Kütz. (62%), *Cryptomonas marssonii* (54%), *Komma caudata* (54%), *P. limnetica* (54%), *Aphanocapsa holsatica* (50%) prevailed.

The average long-term biomass of summer phytoplankton was 7.1 ± 1.32 g/m^3 and its number – 175.5 ± 40.66 mln. cells/l (Table 1). These indicators depended on the amount of diatoms and cyanobacteria, the proportions of which made up 22–97% and 1–68% of the total biomass, as well as 2–88% and 32–96% of the total number, respectively. The greatest quantitative characteristics were registered in 2021, 2022. (7.1 ± 1.41 and 14.8 ± 2.89 g/m^3; 156.3 ± 33.27 and 440.2 ± 43.38 mln. cells/l). At the same time, the following species dominated: *Aphanocapsa delicatissima*, *A. holsatica*, *A. incerta*, *Aulacoseira ambigua*, *Dolichospermum circinale* (Rabenh. ex Born. & Flah.) Wacklin, Hoffmann & Kom., *Microcystis wesenbergii*, *Planktolyngbya contorta*, *P. limnetica, Pseudanabaena limnetica*, *Pseudopediastrum boryanum*, *Scenedesmus quadricauda.* In other years, the average biomass of algae in summer ranged from 2.8 ± 0.29 to 4.4 ± 0.52 g/m^3, its number – from 76.1 ± 4.57 to 94.5 ± 16.83 mln. cells/l. *Aphanocapsa delicatissima, Asterionella formosa, Aulacoseira ambigua, Aulacoseira* sp., *Cymatopleura solea, Dolichospermum viguieri* (Denis & Frémy) Wacklin, Hoffmann

Table 3a. Average number and biomass of zoobenthos of the Sheksna reservoir in August–November 2018–2022. Above the line – average number (N, thous. ind./m^3), below the line – biomass (B, g/m^3).

A group of organisms	Sheksna Reservoir, lake part (Lake Beloye)			Sheksna Reservoir, river part			
	Biotope						
	Profundal	Littoral	Mean	Profundal	Littoral	Bays and river mouths	Mean
Mollusca	104 ± 15.1 / 0.37 ± 0.077	86 ± 17.1 / 1.70 ± 0.433	102 ± 15.2 / 0.51 ± 0.158	43 ± 10.9 / 1.25 ± 0.295	93 ± 13.9 / 0.68 ± 0.159	133 ± 27.3 / 1.12 ± 0.231	83 ± 18.6 / 1.09 ± 0.251
Oligochaeta	307 ± 49.8 / 1.13 ± 0.189	470 ± 48.2 / 1.10 ± 0.202	324 ± 49.6 / 1.12 ± 0.189	365 ± 44.8 / 0.69 ± 0.118	173 ± 24.9 / 0.14 ± 0.022	788 ± 140.8 / 1.58 ± 0.236	457 ± 89.3 / 0.83 ± 0.162
Amphipoda	42 ± 14.6 / 0.20 ± 0.103	37.3 ± 6.3 / 0.33 ± 0.063	41 ± 13.9 / 0.21 ± 0.099	15 ± 4.2 / 0.02 ± 0.002	1544 ± 472.1 / 3.44 ± 0.397	415 ± 138.3 / 0.95 ± 0.109	483 ± 240.8 / 1.02 ± 0.118
Chironomidae	442 ± 85.1 / 1.72 ± 0.254	310 ± 41.6 / 0.90 ± 0.060	428 ± 81.6 / 1.58 ± 0.245	194 ± 24.9 / 0.98 ± 0.221	380 ± 40.3 / 0.88 ± 0.136	1321 ± 246.4 / 2.47 ± 0.785	595 ± 151.6 / 1.40 ± 0.457
Total	**907 ± 117.1 / 3.93 ± 0.546**	**915 ± 87.8 / 3.57 ± 0.632**	**908 ± 114.0 / 3.89 ± 0.552**	**644 ± 57.0 / 3.00 ± 0.339**	**2253 ± 459.3 / 5.33 ± 0.846**	**2808 ± 442.3 / 7.61 ± 1.422**	**1693 ± 346.9 / 4.85 ± 0.910**

Table 3b. Average number and biomass of zoobenthos of the Lake Kubenskoye and Lake Vozhe in August–November 2018–2022. Above the line – average number (N, thous. ind./m^3), below the line – biomass (B, g/m^3).

A group of organisms	Lake Kubenskoye				Lake Vozhe			
	Biotope							
	Profundal	Littoral	Bays and river mouths	Mean	Profundal	Littoral	Bays and river mouths	Mean
Mollusca	340 ± 48.5 / 1.82 ± 0.426	410 ± 52.4 / 1.49 ± 0.458	113 ± 20.2 / 0.28 ± 0.125	266 ± 43.8 / 1.06 ± 0.353	22 ± 9.1 / 0.05 ± 0.018	46 ± 8.8 / 0.09 ± 0.031	30 ± 8.1 / 0.66 ± 0.235	32 ± 8.5 / 0.36 ± 0.167
Oligochaeta	95 ± 101.0 / 1.94 ± 0.438	474 ± 65.3 / 0.31 ± 0.063	298 ± 51.0 / 0.34 ± 0.112	510 ± 76.8 / 0.71 ± 0.241	114.5 ± 10.55 / 0.45 ± 0.080	187 ± 18.6 / 0.44 ± 0.094	192 ± 21.5 / 0.15 ± 0.022	171 ± 18.7 / 0.30 ± 0.067
Amphipoda	109 ± 20.4 / 0.36 ± 0.209	33 ± 9.1 / 1.38 ± 0.553	339 ± 77.7 / 1.01 ± 0.230	166 ± 51.4 / 0.88 ± 0.337	– / –	10 ± 4.9 / 0.17 ± 0.091	3 ± 1.3 / 0.03 ± 0.016	4 ± 2.7 / 0.07 ± 0.050
Chironomidae	249 ± 28.1 / 2.51 ± 0.865	843 ± 196.0 / 2.05 ± 0.503	156 ± 24.8 / 8.74 ± 1.507	411 ± 121.5 / 4.99 ± 1.174	204 ± 22.3 / 0.88 ± 0.163	648 ± 94.9 / 1.55 ± 0.299	700 ± 94.1 / 1.06 ± 0.158	562 ± 84.9 / 1.16 ± 0.209
Total	**1705 ± 148.9 / 7.69 ± 1.156**	**2299 ± 306.0 / 4.93 ± 0.716**	**621.1 ± 65.1 / 9.65 ± 1.472**	**1442 ± 217.6 / 7.59 ± 1.200**	**352 ± 31.5 / 1.39 ± 0.187**	**994 ± 117.9 / 2.58 ± 0.376**	**1047 ± 103.7 / 3.16 ± 0.432**	**859 ± 100.1 / 2.59 ± 0.377**

& Kom., *Melosira varians, Meridion circulare* (Grev.) Ag., *Microcystis novacekii* (Kom.) Compère, *Planktolyngbya contorta, P. limnetica, Pseudanabaena limnetica, Pseudopediastrum boryanum, Snowella lacustris, Tabellaria fenestrata* predominated.

Zooplankton

During the study period, zooplankton of lake Vozhe was characterized by high abundance. The average number of rotifers and crustaceans reached 131.1 ± 11.39 thous. ind./m^3 and biomass – 3.5 ± 0.41 g/m^3. The average biomass of zooplankton was similar throughout the lake. The density of zooplankters in the central part of the lake was 1.5 times higher than in the coastal areas covered by macrophytes (Table 2). The community structure of the open water areas and macrophyte thickets also differed. In the central part of the lake, the majority of the community was formed by copepods. Cladocerans and rotifers had a relatively high biomass. In macrophyte thickets, the proportion of cladocera and copepods in the total number was similar; cladocerans dominated in biomass.

The composition of dominant species of zooplankton of lake Vozhe was diverse. Cyclopes included solely *Thermocyclops oithonoides.* Rather high abundance of *Mesocyclops leuckarti* was recorded only in August 2021. *Daphnia cucullata* and *Sida crystallina* belonged to the dominant complex of Cladocera. In some years, *Daphnia cristata* and *Bosmina coregoni* prevailed. Among rotifers, *Kellicottia longispina, Asplanchna priodonta, Euchlanis dilatata, Trichocerca* sp. dominated.

The lake zooplankton was characterized by significant interannual fluctuations in biomass (CV 68%), associated mainly with a very high biomass of rotifer *Asplanchna priodonta* and cladocera *Sida crystallina* in some years. For instance, the average biomass of *A. priodonta* in the water body was 11.1 ± 2.68 g/m^3 in August of 2022. This indicator for *S. crystallina* made up 1.1 ± 0.57 g/m^3 and 3.5 ± 3.25 g/m^3 in 2018 and 2020, respectively.

The least number and biomass of zooplankton in lake Vozhe were recorded in August of 2019 (66.7 ± 18.17 thous. ind./m^3 and 1.0 ± 0.26 g/m^3, respectively). Here, the average number of zooplankton was high in 2018, 2020, and 2022 with the peak reached in 2022 (192.8 ± 28.20 thous. ind./m^3 and 6.9 ± 1.74 g/m^3).

Zoobenthos

The greatest abundance of zoobenthos of lakeVozhe was noted in the estuarine river sections. In the channels of lake tributaries, oligochaetes *Tubifex newaensis* and *T. tubifex*, while in the thickets – chironomids of the genera *Endochironomus, Glyptotendipes, Cricotopus* were common. On silts of the central part of the lake, among dominants were *Chironomus* sp. and *Procladius* sp., abundance of which varied significantly in different years. The average number of zoobenthos of lake Vozhe in 2018–2022 accounted for 859 ± 100.1 ind./m^2 and biomass – 2.6 ± 0.38 g/m^2 (Table 3b). Both indicators were a bit lower than the long-term averages (Filonenko and Komarova, 2017; Ivicheva and Filonenko, 2015). The best quantitative characteristics of zoobenthos for the analyzed period were noted in 2021 (number – 905.2 ind./m^2, biomass – 4.32 g/m^2).

The number and biomass of zoobenthos were maximum in the bays near the river mouths (1047 ± 103.7 ind./m^2 and 3.20 ± 0.43 g/m^2) and on sands of the littoral (994 ± 117.9 ind./m^2 and 2.58 ± 0.38 g/m^2) where chironomid larvae dominated. The least number of zoobenthos was recorded for muds of the deep-water area (352 ± 31.5 ind./m^2 and 1.4 ± 0.43 g/m^2) populated only by *Chironomus sp.* and *Procladius sp.*; in some periods, the animals were completely absent there.

Discussion

In 2018–2022, cyanobacteria and diatoms along with green, cryptophytic and other algae formed the floristic and quantitative basis of phytoplankton in large water bodies of the Vologda Oblast. In all water bodies, the genus *Scenedesmus* stood out for its species richness. Species of the genus *Aulacoseira* were frequently found throughout.

In summer 2018–2022, the average biomass of algae was the highest in lakes Beloye, Vozhe, Kubenskoye and a bit lower – in the river part of the Sheksna reservoir. Maximum phytoplankton number was noted in lake Vozhe. According to the Trifonova classification (1990), the river part of the Sheksna reservoir, lakes Kubenskoye and Vozhe had eutrophic (biomass 5–10 g/m^3), while Beloye – highly eutrophic status (more than 10 g/m^3). In 2021–2022, high number and biomass of algae were observed in all water bodies when a large number of cyanobacteria, green and warm-water diatoms appeared during the prolonged period of warm weather.

The contribution of diatoms to the total biomass and number was, on average, the highest in the river part of the Sheksna Reservoir (80% and 38%, respectively). Species of the genus *Aulacoseira* were main dominants among diatoms throughout the growing season (Makarenkova, 2013). The predominance of *Aulacoseira species* was typical for plankton of large water bodies (Korneva, 2015; Letanskaya and Protopopova, 2012; Otchenash et al., 2021). In lake Beloye, the largest share in number and biomass of phytoplankton (45% and 85%) fell on cyanobacteria that annually resulted in intensive water bloom (Makarenkova, 2018). In lake Vozhe, cyanobacteria number was also significant (71%). At the same time, the structure of the cyanobacteria complex in both lakes differed: in Beloye – quantitative predominance of nitrogen fixers, in Vozhe – non-heterocyst species were observed. The reduced share of nitrogen fixers in the dominant complex of lake Vozhe could be induced by the inhibitory effect of ammonium nitrogen, i.e. the predominant form of mineral nitrogen (increased in late XX century) (Borisov, 2006). In the last few decades, the composition of cyanobacteria in this lake remained the same (Korneva et al., 2021; Makarenkova, 2012; stock materials of VologodNIRO, unpubl.). The predominance of non-heterocyst species among cyanobacteria was also marked in the Volga reservoirs (Korneva, 2015).

By zooplankton composition, large fishery reservoirs in the Vologda Oblast and the taiga zone demonstrate similarity (Pidgaiko, 1984). The community of the Sheksna reservoir was the richest in species (about 180 species). Relatively rare and scarce zooplankton species were found in this reservoir during the implemented comprehensive studies (Lazareva, 2022; Lazareva et al., 2013; Lobunicheva et al., 2022a). For example, such invasive species as *Kellicottia bostoniensis, Brachionus diversicornis* (Daday, 1883), *Diaphanosoma orghidani* Negrea, 1982 (Lazareva, 2008; Lazareva et al., 2013; Lobunicheva et al., 2022b) were detected among zooplankters only in the Sheksna Reservoir.

In all water bodies, summer zooplankton varied in number and biomass during the 5-year study period that was previously noted for some other reservoirs as well (Dumnich and Lobunicheva, 2016; Dumnich et al., 2021; Lobunicheva et al., 2022a). The level of phytoplankton development and water temperature were among driving factors influencing zooplankton abundance (Lazareva, 2010). Summer periods of 2021-2022 were very warm. In the Northwestern Federal District, the anomaly of air temperature made up +2.41 °C in 2021 and +2.31 °C in 2022 (Doklad ob osobbenostyakh..., 2023). As for water, it was by 1.8–2.0 °C higher than in 2018–2020. In addition, higher phytoplankton biomass during this period provided abundant zooplankton in 2021–2022.

The zooplankton structure was quite stable and similar in all studied water bodies. In August, copepods were characterized by the highest number among zooplankters, whereas cladocerans – by maximum biomass. Only in lake Kubenskoye, the average biomass of cladocerans and copepods was equal (Table 2). The composition of dominants in water bodies varied little over the years. The lake and river sections of the Sheksna Reservoir had similar zooplankton structure. Changes in the share of *Cyclops* nauplii in the total number of zooplankton were the most pronounced. Lake Vozhe had the most diverse composition of dominants.

The greatest spatial differences in the structure and abundance of zooplankton were characteristic of the river part of the Sheksna Reservoir with its pronounced deep-water zone and numerous bays overgrown by macrophyte thickets favorable for the community formation with excellent features. In lakes Kubenskoye and Vozhe with their large shallow areas occupied by macrophytes, the spatial structure of plankton largely depended on wind mixing.

In the study period (August 2018–2022), the highest average number and biomass of zooplankton were typical for lake Vozhe (Table 2). The number and biomass of zooplankton in 2018–2022 and 1983–1984 were similar (Andronikova, 1985). From 2018, rather high zooplankton abundance was explained by mass development of some species (*Asplanchna priodonta, Daphnia cucullata, Sida crystallina*) almost throughout the lake. Previously, some investigators reported about sharp growth of these species number (Andronikova, 1985; Smirnova, 1978). The noted in recent decades increased zooplankton development in lake Vozhe (Dumnich et al., 2021) was caused by high summer water temperatures favorable (in some years) for the development of many zooplankters, expansion of macrophyte thickets in certain parts of the reservoir (Filonenko and Komarova, 2015), and growing density of small-sized planktonic algae (Dumnich et al., 2021). In terms of a food base, the lake was characterized as a water body with an average to above average food base (Pidgaiko et al., 1968).

The average number and biomass of zooplankton in the lake and river sections of the Sheksna Reservoir in 2018–2022 did not differ from the long-term values (Dumnich and Krylov, 2002; Lazareva, 2022; Lazareva et al., 2013; Lobunicheva et al., 2022a; Smirnova et al., 1981). In lake Kubenskoye, a slight reduction in the average zooplankton biomass of 2018–2022 (as compared to 1970–1980) was noted (Nikolaev, 1977; Rodionov et al., 1987). In contrast to the 2000s, the average number and biomass of zooplankton increased (Dumnich and Lobunicheva, 2016; Dumnich et al., 2021). The Sheksna reservoir is currently classified as a water body having an average food base, and Lake Kubenskoye – a poor one (Pidgaiko et al., 1968).

Quantitative indicators of zoobenthos in the study reservoirs differed by almost three times. Biomass was the highest in lake Kubenskoye and the lowest – in lake Vozhe. By the level of zoobenthos development, lake Beloye and the river part of the Sheksna Reservoir belong to water bodies with an average food base, lake Kubenskoye – above average, and lake Vozhe – the poor one (Pidgaiko et al., 1968).

In all water bodies, the main share in the total number and biomass falls on Chironomidae, Oligochaeta, and Mollusca. The proportion of Chironomidae in the total number is the greatest in lakes Vozhe (up to 65%) and Beloye (47%). Most zoobenthos biomass is formed of chironomid larvae, especially large *Chironomus* sp. Larvae abundance and the number of their generations directly depend on air temperature in the spring-summer period. Windless weather is optimal for chironomid swarming. Often, the prevailing wind direction affects the place of mass emergence of chironomid adults and further spatial distribution of zoobenthos in water bodies. The most favorable conditions for the development of insect larvae are formed in the littoral, a significant part of which can be drained during the low water period. Mass development of larvae in shallow waters during very dry water years subsequently brings to Chironomidae preimagos loss, including the reduced total number and biomass of zoobenthos. Oligochaets are represented by tubificids *Limnodrilus hoffmeisteri, Tubifex nevaensis* and *T. tubifex.* In the region, the best conditions for tubificids are formed on the moderately silted sands of the coastal shoals and precipices. Habitats favorable for the existence of these organisms are often small in area, periodically washed away and substituted by other substrates (sand, peat). For example, the sites of oligochaete assemblages in the profundal of lake Beloye are mosaic and change their position in different years (Filonenko and Ivicheva, 2018). Oligochaeta predominate in lake Kubenskoye (up to 35%).

In the Sheksna reservoir and lake Kubenskoye, among the dominants is *Gmelinoides fasciatus* – the only invasive species of amphipods currently inhabiting the water bodies of Vologda Oblast and locally producing high biomass. In the littoral of the riverine part of the Sheksna Reservoir, the average number and biomass of this crustacean are 1544 ± 472.1 ind./m^2 and 3.44 ± 0.397 g/m^2, respectively. This species has widely populated all water bodies of the Volga-Baltic and North-Dvina waterways of the Vologda Oblast (Ivicheva and Filonenko, 2019). First discovered in the Toporninsky canal of the North Dvina water system in 2010 (Ivicheva and Filonenko, 2019), *G. fasciatus* regularly appears in lake Kubenskoye as well. At present, this species is common in the lake littoral.

In the reservoirs of Vologda Oblast, assemblages of *G. fasciatus* are found in the narrow strip along the coast among pebbles and large plant detritus, fouling or in dense thickets of helophytes. In the deeper parts of the reservoirs, single amphipods are detected regularly. Perhaps, they come here from shallow waters. Such habitat preferences make *G. fasciatus* a prey object just for limited fish species of a narrow age range. *G. fasciatus* has been found in all large water bodies of the region, except for lake Vozhe. Not numerous *Gammarus lacustris* G.O. Sars, 1863 is the only amphipod representative in this lake.

In lakes, small bivalve mollusks dominate. In the river part of the Sheksna Reservoir, species of the genus *Viviparus* are subdominants. Unlike many water bodies in the European part of Russia (Perova et al., 2018; Pryanichnikova et al., 2011; Shcherbina and Buckler, 2006), the lakes and reservoirs of Vologda Oblast are not distinguished by the high number of *Dreissena polymorpha* (Pallas, 1771). *Dreissena* is able to develop intensively only on the remains of wood. The sites of flooded forests are confined to peaty substrates, where zoobenthic organisms are practically absent. A small number of benthic organisms is observed only in thickets of macrophytes. Empty shells of *D. polymorpha* are often found on the shores of lakes Beloye and Kubenskoye and very rare in soil samples. Locally, this species forms druses on the wood remains in shallow waters.

The structures of benthic communities in deep-water sites and in macrophyte thickets differ. *Chironomus* sp., oligochaetes *L. hoffmestery, T. newaensis,* and *T. tubifex* dominate in muds of the deep – water zone. Overgrown biotopes in large lakes of the region occupy relatively small areas. In such placed, benthic organisms are noted both in the bottom and the surface of plants. The composition of the phytophilic fauna is practically independent of the macrophyte composition (Ivicheva et al., 2021). Small oligochaetes of the genera *Nais* and *Stylaria* are numerous in these communities; phytophilic chironomids (*Endochironomus albipennis* (Meigen, 1830), *Glyptotendipes gripekoveni* (Kieffer, 1913), *Cricotopus* gr. *sylvestris* is the base of biomass.

Conclusion

In 2018–2022, plankton and benthos of large fishery reservoirs of the Vologda Oblast were characterized by stable composition and interannual fluctuations in number and biomass. Plankton abundance depended on intensity of water heating in spring and summer. In 2021–2022, the recorded long summer periods of high air temperatures induced a significant increase in number and biomass of cyanobacteria, green and warm-water diatoms, certain species of cladocerans and rotifers. As a result, the average values of the total number and biomass of phyto- and zooplankton in most large water bodies of the region also increased.

In terms of the average long-term phytoplankton biomass, the river part of the Sheksna Reservoir, lakes Kubenskoye and Vozhe had eutrophic and lake Beloye – highly eutrophic status in 2018–2022. Diatoms and cyanobacteria dominated in all reservoirs. The number of diatoms was higher in the river part of the Sheksna Reservoir, cyanobacteria – in lake Beloye. Water bloom in late summer was observed in all reservoirs; it was especially strong in lake Beloye, where macroscopic floating masses persisted until autumn.

The greatest abundance of zooplankton was characteristic of lake Vozhe (food base: above average). By average biomass, Lake Beloye and the river part of the Sheksna Reservoir were classified as water bodies with the average and lake Kubenskoye – the poor food base. In all studied water bodies, copepods formed the basis of zooplankton number in late summer, while cladocerans – most biomass.

By zoobenthos abundance, lake Beloye and the river part of the Sheksna Reservoir can be characterized as water bodies with the average; lake Kubenskoye –above average, and lake Vozhe – with the poor food base. The dominant groups in all water bodies are chironomid larvae, oligochaetes and mollusks. A relatively high abundance of chironomids is typical for lakes Beloye and Vozhe, whereas of oligochaetes – for lake Kubenskoye.

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