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Article

Current state of phytoplankton and microphytobenthos of the Chernaya River (Leningrad Oblast, the Baltic Sea basin)

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Abstract. The paper presents the data on the long-term studies of phytoplankton and microphytobenthos of the Chernaya River (Vyborg region), including the hydrochemical water composition and particle-size distribution in soil. Species richness of phytoplankton is higher than that of microphytaobenthos. In both communities, diatoms prevail; the dominant species is *Aulacoseira subarctica* (O. Müller) E.Y. Haworth. The seasonal dynamics of phytoplankton abundance is typical for water bodies in northwestern Russia.

Keywords: diatoms, Bacillariophyta, *Aulacoseira subarctica*

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Научная статья

Современное состояние фитопланктона и микрофитобентоса реки Чёрной (Ленинградская область, бассейн Балтийского моря)

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Аннотация. В работе представлены данные многолетних исследований фитопланктона и микрофитобентоса реки Черной (Выборгский район), а также гидрохимического состава воды и гранулометрического состава грунта. Видовое богатство фитопланктона выше, чем микрофитобентоса. В обоих сообществах преобладали диатомовые водоросли, видом–доминантом являлась *Aulacoseira subarctica* (O. Müller) E.Y. Haworth. Сезонные изменения обилия фитопланктона имели типичный для водоемов северо-запада России характер.

Ключевые слова: диатомовые водоросли, Bacillariophyta, *Aulacoseira subarctica*

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Introduction

The territory of Russia is rich in rivers, 95% of which are small watercourses (Bogatov and Fedorovsky, 2017). They directly provide a full flow of large rivers (Fedorovsky, 1985). SSince streams are less economically exploited, they remain among the least studied (Semeykina, 2014). Small rivers of Leningrad Oblast are not an exception; their aquatic communities have been poorly investigated despite the important role in the formation of the catchment area of larger water bodies. They are home to a diverse range of animals and plants. Often, just small rivers are inhabited by rare protected species. Being the first link in the food chain, algae are the important component of the river community. The exceptional diversity of algae makes them an integral object for the environmental monitoring.

The aim of this study is assessing the diversity of algal communities of a small river and seasonal dynamics of major taxonomic groups (Bacillariophyta, Cyanoprocariota and Chlorophyta).

Materials and methods

A typical small watercourse – the Chernaya River of 18 km long, running through the Karelian Isthmus in the Vyborg region, originates from Lake Gladyshevskoye and inflows to the Gulf of Finland. In a sampling site (N 60°13′15.74″ E 29°30′56.26″, 6 km from the mouth), its width makes up 15–20 m with depths from 0.5 to 2.5 m; the flow velocity in the reaches is 0.75 m/s, in the riffles – 1.5 m/s, and near the shore – 0.36 m/s.

Phytoplankton and microphytobenthos samples were collected from June 2017 to late September 2020. Over the study period, 19 phytoplankton and 13 microphytobenthos samples were collected and processed.

Phytoplankton was collected from a depth of 10–40 cm using a 1-liter bottle. The samples were fixed with 40% formaldehyde (15–20 ml) and concentrated by the sedimentation method to a volume of 15–60 ml. TTo determine the number, biomass, and species composition of algae, three drops of the premixed sample were taken from the concentrated volume and placed in a 0.02 ml Nageotte chamber for cell counting in 20 bands; the remaining bands were examined for the presence of large and/or single forms. To determine the algae biomass in a specimen, we measured length and width of cells, and in some cases height. For a taxonomically minor group of algae, 10 to 20 measurements were made. If fewer than 10 cells were found, the measurements number was maximum possible for this sample. The measurement results were then averaged to estimate cells size by the formulas from an electronic resource or methodological recommendations (Nordic Microalgae[1]; Radchenko et al., 2010). If a formula was missing, we derived it for the detected algae figures based on the geometric similarity method (Radchenko et al., 2010).

Microphytobenthos was collected from the 2–3 cm top soil layer using a 7 cm^2 beaker, then fixed with a 40% formaldehyde and carefully mixed. To estimate the number, biomass and species composition of

[1] Nordic Microalgae, Sweden. Web page. URL: http://nordicmicroalgae.org (accessed: 11.05.2023).

microalgae, one milliliter of a liquid was taken by a pipette, followed by careful mixing of the content. The obtained volume was placed in an empty container. Prior to processing, the specimen was diluted ten- or twenty-fold with a distilled water and mixed. Then, 3 drops of the obtained content were introduced to a 0.02 ml Nageotte chamber to count the cells in the sample and to define biomass. The procedure for further biomass calculations were similar to that applied in processing phytoplankton samples. When dealing with microphytobenthos, we used the methodological recommendations for studying phytoperiphyton in small rivers (Komulainen, 2003).

Diatoms were determined in diatom slides under a scanning electron microscope. Other taxonomic groups were identified by means of a light microscope in the course of sample processing. For identification, we used the following Keys: Komärek and Anagnostidis (1998, 2005), Round et al. (1990), Tsarenko (1990), Zabelina et al. (1951).

The data on hydrophysical and hydrochemical characteristics of water (temperature, pH and electrical conductivity, concentration of dissolved organic matter (COD, permanganate oxidizability)), the granulometric composition and organic matter content in soils were obtained (2018) via applying the standard methods (Methods..., 2013).

Results and discussion

The formation of the hydrochemical and hydrological regime of the Chernaya River depends on the seasonal dynamics of physicochemical features. Such abiotic characteristics as water temperature, organic matter content, pH and electrical conductivity undergo seasonal variations. The granulometric composition, organic matter content in soil and color do not change significantly during the year.

The highest and lowest water temperatures were recorded in July and December.

Within-the-year concentrations of organic matter in the water were high and varied from 9.9 to 16.9 mgO_2/l. For instance, the lowest values were noted during summer low water, while the highest in the flood period. Due to the increased content of humic substances, northern rivers are characterized by a high degree of oxidation (Alekin, 1953). Seasonal increase in organic matter concentrations is associated with their entry to the river from the catchment area.

The river water had low mineralization (55–116 mSm), pH values changed during the year from slightly acidic (6.1) to weakly alkaline (8.9), while pH in Lake Gladyshevskoye varied in the range from 8.7 to 9.9 (Trifonova et al., 2016). Thus, in the river, compared to the lake, the range of pH is wider and closer to acidic indicators. These and other differences (compared to the data on the lake and outflowing river) are owing to a different water exchange in lakes and rivers (Alekin, 1953). It is worth noting that in our investigations, sampling was implemented not at the source of the river, but closer to its mouth that makes the differences more pronounced. Soils of the Chernaya River are mainly sandy with gravel inclusions. The predominant fraction smaller than 0.25 mm accounted for up to 90% of soil sample weight. Annual changes in particle size distribution were insignificant. The content of organic matter in soil averaged from 1 to 3.5%. Maximum values were registered in June and November (3.4 ± 1.1% and 3.2 ± 1.7%), whereas the minimum – in July (1.2 ± 0.3%) and in mid-September (1.7 ± 0.5%).

In phytoplankton of the Chernaya River, we identified the representatives of 7 algae divisions: Bacillariophyta, Chlorophyta, Cyanoprocariota, Charophyta, Euglenophyta, Dinoflagellata and Ochrophyta. A total of 86 taxa below the genus rank were detected. Diatoms dominated by the number of taxa (Table 1). In Lake Gladyshevskoye, nine divisions of algae were recorded (Trifonova et al., 2016), where, unlike the river, the representatives of divisions Cryptophyta and Raphidophyta (except for Dinoflagellata) were found.

Diatoms formed the phytoplankton structure, making up from 40% in spring to 87% in winter (by abundance) and from 63% in spring to 90% in winter (by biomass). Blue-green and green algae were subdominants. They accounted for about 13% in winter and to 60% in spring (by abundance) and from 5% in autumn to 39% in spring (by biomass). According to the literature, diatoms also dominated in Lake Gladyshevskoye (Trifonova et al., 2016). Similar data were obtained for lakes Krasnoye and Morozovskoye (the Karelian Isthmus), located in the Priozersk region at a distance of 60 and 70 km from the Chernaya River, where diatoms appeared to be the most diverse group of algae (Trifonova et al., 2014).

The plankton of the Chernaya River included primarily diatoms of the orders Aulacoseirales, Naviculales, Cymbellales, Fragilariales, Tabellariales, Stephanodiscales, Achnanhtales, and Bacillariales.

The species *Aulacoseira subarctica* (Fig. 1) played a significant role in the riverine plankton and benthos, accounting for about 80% of the total population throughout the study period. In 2010–2015, the representatives of the genus *Aulacoseira* in Lake Gladyshevskoye were frequently encountered as well; the species *Aulacoseira ambigua* (Grunow) Simonsen and *A. granulata* (Ehrenberg) Simonsen were also detected (Trifonova et al., 2016). The dominance of species of the genus *Aulacoseira* in plankton is typical for water bodies of northwestern Russia (Genkal and Trifonova, 2005). In our case, the dominance of this genus was presumably due to the most favourable conditions for planktonic forms, i.e. great depth and transparency. The cells were assumed to come from the lake due to drift (Komulainen, 1996).

The representatives of 5 algae divisions were recorded in microphytobenthos: Bacillariophyta, Chlorophyta, Cyanoprokaryota, Charophyta and Euglenophyta. A total of 64 taxa of a rank below genus were detected. Diatoms dominated by the number of taxa (Table 1). According to the literature, 7 divisions were identified in periphyton of small rivers of the Karelian Isthmus (Komulainen, 1996), including the representatives of the red, golden algae and dinoflagellates divisions, not found in the Chernaya River microphytobenthos.

Diatoms dominated in microphytobenthos, making up from 75% in summer to 90% in winter (by abundance) and from 67% in summer to 99% in winter (by biomass). Blue-green algae were subdominants, accounting for 1% in spring to 20% in summer and autumn (by abundance) and 1% in spring to 22% in summer (by biomass).

Diatoms in microphytobenthos were basically represented by taxa from the orders Achnanthales (6), Eunotiales, Aulacoseirales, Cymbellales (3 each), Fragilariales, Tabellariales, Naviculales (2 each), Stephanodiscales, Thalassiophysales, Bacillariales, Surirellales (1 each). Diversity of single-raphe (order Achnanthales) is explained by the predominance of a sand fraction in soil because of the species adherence to sand grades.

Phytoplankton and microphytobenthos had common 36 taxa from the diatoms division: 7 from blue-green, 8 – green division, 4 – charophyte, and 2 – euglenophyte (Table 1). In microphytobenthos, the

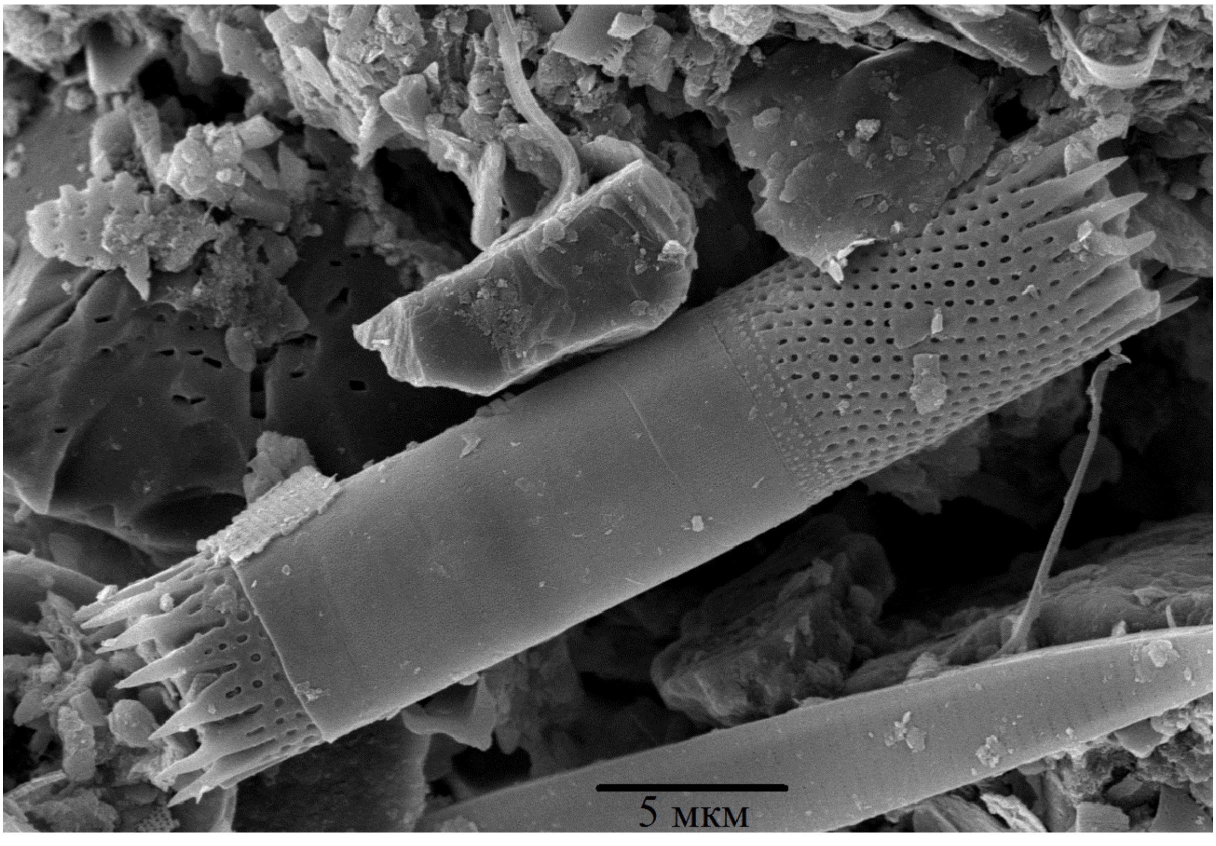

Fig. 1. *Aulacoseira subarctica* (photo by M.I. Yurchak).

Table 1. Taxonomic composition of the phytoplankton and microphytobenthos of the Chernaya River

Division	Number of species		
	Phytoplankton	Microphytobentos	Common taxa for phytoplankton and microphytobentos
Bacillariophyta	40	42	36
Chlorophyta	23	8	8
Cyanoprokaryota	12	7	7
Charohyta	5	5	2
Euglenophyta	2	2	2
Dinoflagellata	2	-	0
Ochrophyta	2	-	0
Total	**86**	**64**	**55**

significance of diatoms (66% of the total diversity) was higher than in plankton (47%) that is characteristic of water bodies of the temperate zone (Komulainen, 2004). Green and blue-green algae demonstrated greater richness in plankton (27% and 14% of the total phytoplankton diversity, respectively). The Cyanoprocariota/Chlorophyta ratio in phytoplankton was 1:2, being typical for the algal flora of northern water bodies (Komulainen, 1996). At the same time, this indicator in microphytobenthos was close to 1:1. Note that S.F. Komulainen (1996) and other researchers reported about the similar difference for phytoplankton and periphyton.

Peaks in algae abundance in the plankton and microphytobenthos of the Chernaya River were recorded in spring and early autumn (Figs. 2–5), which is typical for small rivers in northwestern Russia. Maximum abundance of phytoplankton in spring and autumn reached 5.8 and 4 million cells / l in different years (Fig. 2), whereas this indicator for microphytobenthos in spring and autumn peaks made up 0.08 and 0.48 million cells/cm^2, respectively (Fig. 4).

The number of phytoplankton in the Chernaya River was within 0.02–5.8 million cells/l (Fig. 2) and its biomass 0.16–9.9 mg/l (Fig. 3). A comparison of our data on the rheophilic phytoplankton biomass with the results obtained by I.S. Trifonova et al. (2018) for the lake phytoplankton suggest that the lowest biomass values for the river phytoplankton (0.02 mg/l) are several times less than those for limnophytoplankton (1.6 mg/l). As for maximum values, they are similar (9.9 and 10.1 mg/l, respectively). In some small rivers of Leningrad Oblast, this indicator made up 0.12–1.01 mg/l (lower reaches of the Dudergofka), 0.05–0.10 mg/l (middle reaches of the Starozhilovka), 4.9–33.6 mg/l and 2.8–3.6 mg/l (upper and lower reaches of the Kamenka in the northwest of Leningrad Oblast) (Pavlova, 2016).

The number of microphytobenthos in the Chernaya River varied from 0.002 to 0.48 million cells/cm^2 (Fig. 4), biomass – from 0.06 to 10 mg/cm^2 (Fig. 5). We compared the obtained data on microphytobenthos and phytoperiphyton of small rivers of the Republic of Karelia (Komulainen and Morozov, 2007). The number in the rivers Neglinka (1–1816 thous. cells/cm^2) and Lososinka (2–8230 thous. cells/cm^2) and biomass (0.1–23.4 mg/cm^2 in the Neglinka River and 0.1–31.0 mg/cm^2 in the Lososinka River) varied similarly.

During our studies, mass development of cyanoprokaryotes, noted in some other rivers of the region, was not recorded in plankton and benthos of the Chernaya River (Trifonova et al., 2001).

In the Chernaya River, spring and autumn peaks of abundance occurred in different months because of annual temperature fluctuations in northwestern Russia[2]. In June 2017, there was one pronounced

[2] Rp5. Weather information. Web page. URL: https://rp5.ru/%D0%90%D1%80%D1%85%D0%B8%D0%B2_%D0%BF%D0%BE%D0%B3%D0%BE%D0%B4%D1%8B_%D0%B2_%D0%A1%D0%B0%D0%BD%D0%BA%D1%82-%D0%9F%D0%B5%D1%8

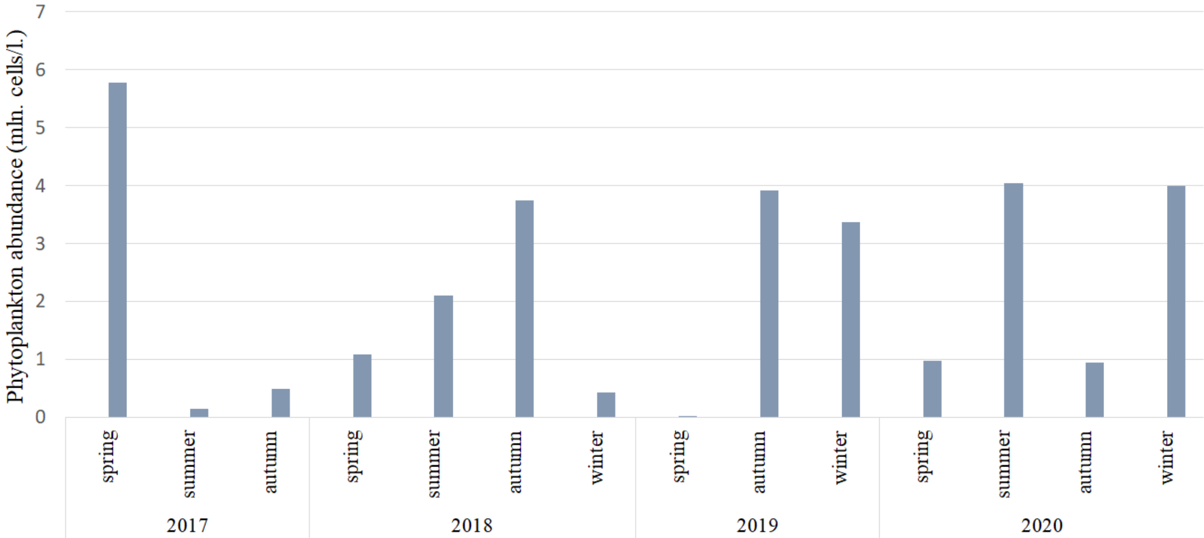

Fig. 2. Seasonal dynamics of phytoplankton number (million cells/l) in the Chernaya River.

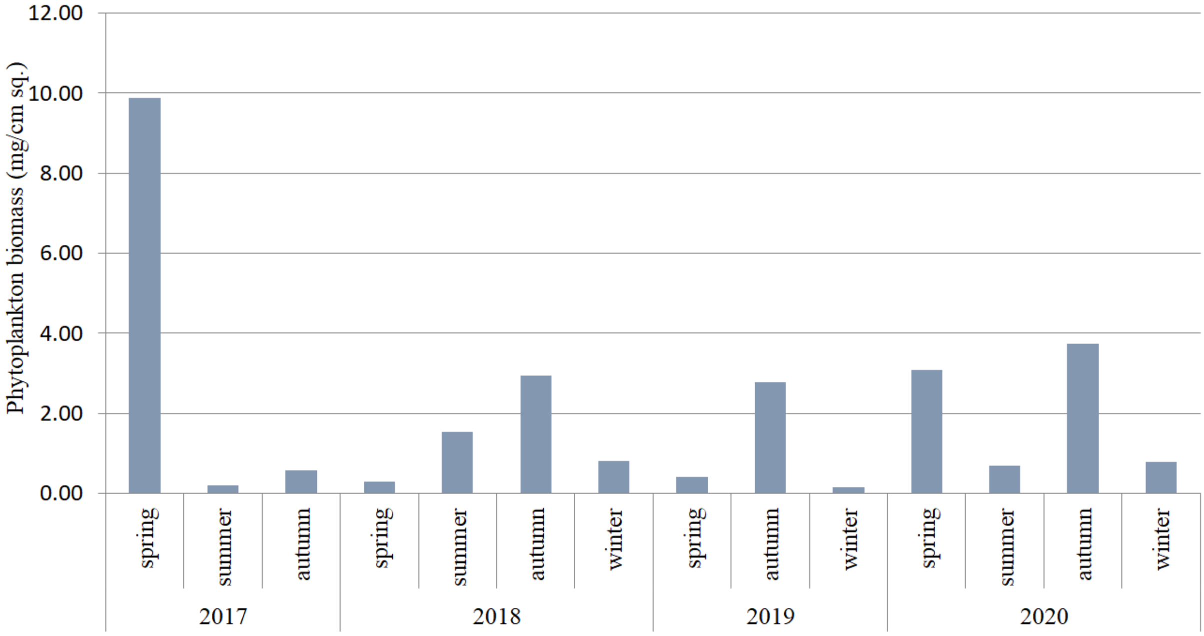

Fig. 3. Seasonal dynamics of phytoplankton biomass (mg/l) in the Chernaya River.

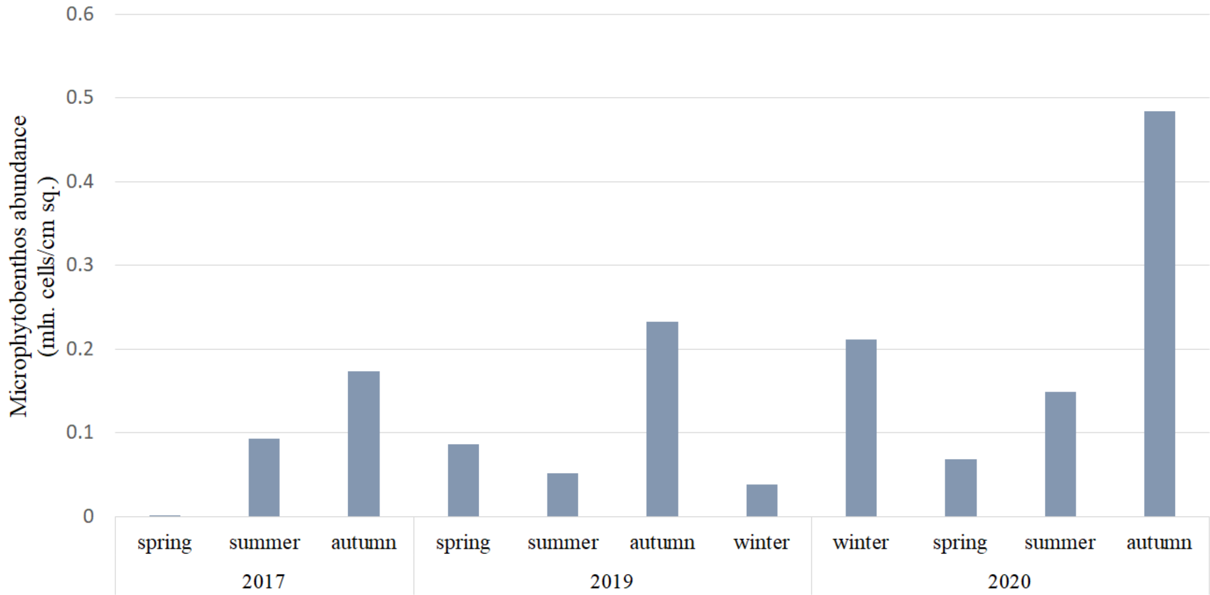

Fig. 4. Seasonal dynamics of microphytobenthos number (million cells/cm[2]) in the Chernaya River.

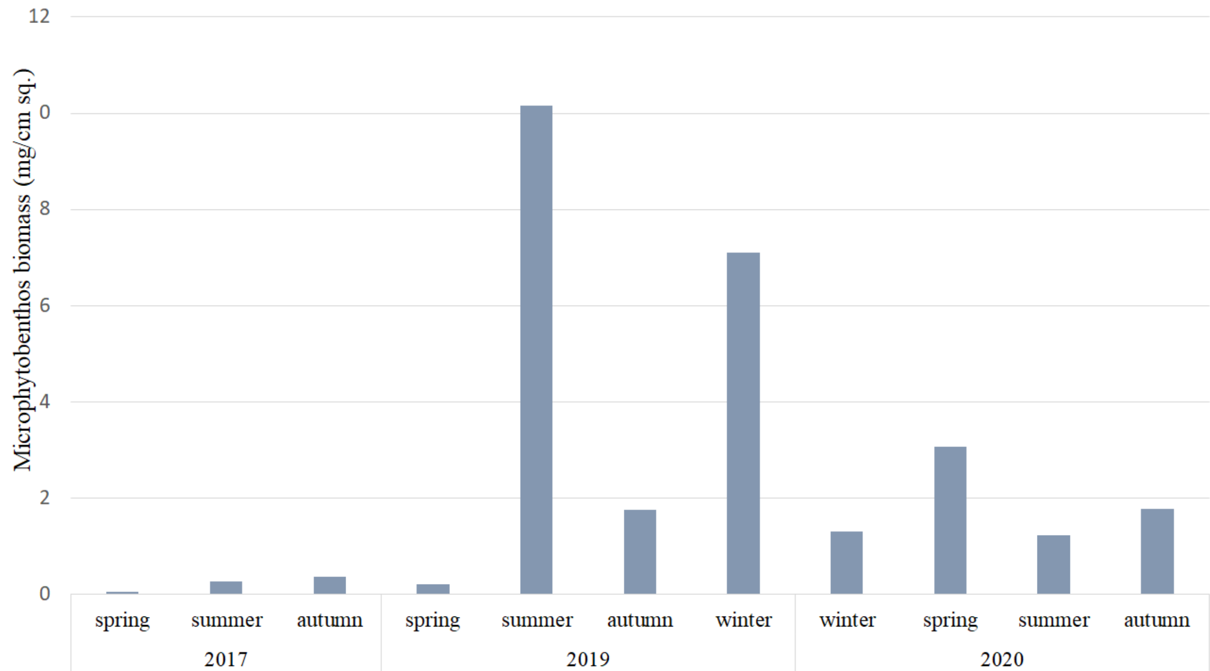

Fig. 5. Seasonal dynamics of microphytobenthos biomass (mg/cm[2]) in the Chernaya River.

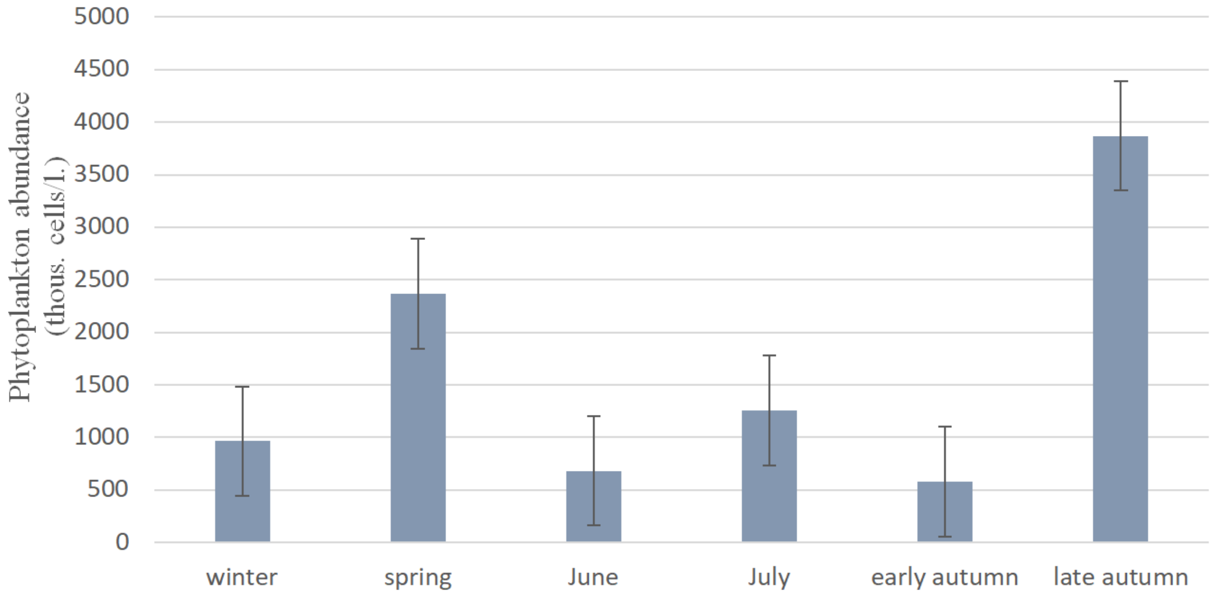

Fig. 6. Interannual dynamics of phytoplankton number (thous. cells/l) in the Chernaya River (averaged data for 2018, 2020)

peak in plankton (0.15–5.8 million cells/l). In 2018, such peaks occurred in July and September (0.44–3.7 million cells/l). In 2019, the maximum number of cells was recorded in April and October (0.02–3.9 million cells/l). In 2020, peaks were noted in May and at the end of September (0.95–4.05 million cells/l). In October 2017, there was one peak in microphytobenthos (0.002–0.2 million cells/cm^2). In 2018, it was recorded only in September because high water in May hindered microphytobenthos sampling (0.04–0.23 million cells/cm^2). The only sample was taken in October 2019 during the autumn plankton peak (0.6 million cells/cm^2). In 2020, the maximum indicators were recorded in June and at the end of September (0.07–0.48 million cells/cm^2) (Fig. 6). The applied statistical methods did not confirm the interannual variability because of large spread of values and high standard errors. The total number and biomass varied significantly depending on the year. For microalgae of northwestern Russia, 2–3 order annual fluctuations in abundance are typical.

Conclusion

As compared to microphytobenthos, phytoplankton of the Chernaya River was characterized by a greater taxa diversity (phytoplankton: 86 taxa from 7 divisions; microphytobenthos: 64 taxa from 5 divisions). Diatoms dominated, green and blue-green algae were subdominants in plankton and microphytobenthos. *Aulacoseira subarctica* was found in all samples, accounting up to 80% in number and biomass.

For plankton and microphytobenthos, two characteristic peaks of abundance were noted in spring and autumn. No significant interannual dynamics in abundance or taxonomic composition were observed. Shifts in interannual abundance peaks, especially in spring, were caused by changes in weather conditions, which is typical for northwestern Russia.

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