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RESEARCH ARTICLE

Phytoplankton as an indicator of the current ecological status of the Ob River

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Abstract
The species composition, taxonomic structure, and the dominant complex of algae, and the distribution of phytoplankton abundance in the studied watercourse were identified based on data obtained for phytoplankton from the Ob River (from Tomsk to Salekhard) in summer 2019. Green algae (division Chlorophyta) make up the basis of the phytoplankton abundance in the river. The dominant complex is represented mainly by centric diatoms (genera *Aulacoseira*, *Cyclotella*, *Stephanodiscus*) and non-heterocyst forms of cyanoprokaryotes (genus *Aphanocapsa*). The numbers and biomass of phytoplankton gradually decrease downstream of the Ob River; below the confluence of the Irtysh River, the edge effect occurs: increase in the diversity and density of organisms at the boundaries of ecosystems. Compared to the previous studies, the proportion of green and euglena algae, and cyanoprokaryotes in the taxonomic spectrum of phytoplankton increased, the composition of the dominant complex enriched, including due to non-heterocyst forms of cyanoprokaryotes, and the trophic status of the river increased to the category of eutrophic waters.

Keywords
Dominant complex, phytoplankton, species composition, taxonomic structure, trophic status

Introduction

The Ob is one of the largest rivers in Western Siberia, Russia and the planet as a whole. In terms of the basin size (2,990 thousand km²), it takes the first place in Russia, and in the water content, it is the third after the Yenisei and the Lena rivers. The Ob is a lowland river with a small fall, a vast valley and floodplain. The total length of the river is 3,680 km. With respect to the nature of the valley and watercourse, the river is conventionally divided into 3 parts: the upper part stretches from the confluence of the Biya and the Katun to the Tom mouth (1,020 km), the middle part stretches from the Tom to the Irtysh mouth (1,500 km), and the lower part stretches from the Irtysh mouth to the Ob Bay (1,160 km) (Plaschev and Chekmarev 1967; Mitrofanova 2019; Yermolaeva et al. 2021).

The Ob is of great national economic significance (Stoyascheva, Rybkin 2014). The river is the most important transport artery of Western Siberia; its upper and middle reaches are occupied by large cities with developed industry, its basin is rich in oil, gas, and coal. Fishing is developed. The only artificial reservoir built in the upper reaches is the Novosibirsk reservoir (Long-term dynamics... 2014).

Phytoplankton, the first link in the trophic chain of water bodies, is of great relevance for assessing their ecological status. Phytoplankton studies show the current status of water bodies and predict the direction of their changes. Phytoplankton is crucial for indication of natural modifications in freshwater ecosystems under anthropogenic impact (Abakumov 1991).

Phytoplankton from different parts of the Ob, its sor system and the Ob Bay has been regularly studied, with focus placed on its species composition and taxonomic structure (Popova and Safonova 1961; Yakubova 1961; Kuksn 1964, 1965, 1970a, b; Kiselev 1970; Kuksn et al. 1972; Safonova 1972; Semenova and Aleksyuk 1989; Genkal, Naumenko 1985; Genkal and Semenova 1989, 1999; Naumenko 1992, 1994, 1998; Mitrofanova 1996; Semenova and Naumenko 2001). The most comprehensive study of phytoplankton along the entire length of the Ob River was performed at the end of the 20th century (Naumenko 1995, 1996, 1998). The studies of the composition and abundance of phytoplankton, other indicators of its development, and the content of chlorophyll-a are currently underway to assess the trophic status of the river, the quality of its waters, and intensity of self-purification processes. The studies of phytoplankton employ data obtained for different parts of the river from the upper reaches to the lower ones (Kirillova and Mitrofanova 2002a, 2002b; Kirillov et al. 2010; Mitrofanova 2015, 2019; Mitrofanova 2016).

Meanwhile, an increased anthropogenic impact on the Ob-Irtysh basin (Puzanov et al. 2017) and climatic changes (Savkin and Dvurechenskaya 2018; Savkin et al. 2018) can affect the ecological status of the river. Therefore, the study of phytoplankton in the Ob River is of great importance to assess the status of its ecosystem.

The aim of the study was to assess the current ecological status of the Ob River based on structural parameters of phytoplankton.

Materials and methods

The study employs data obtained in processing of 43 quantitative and 21 qualitative samples of phytoplankton from the Ob River taken along the route from the village of Melnikovo (upper part of the Ob) to the mouth of the Irtysh River (20 km below the confluence of the Irtysh) in July 2019, and near the city of Salekhard in the first decade of August (Fig. 1).

It is known that data obtained in summer most representatively show the ecological status of water bodies, since their cenoses are most fully developed at this time, and their self-purification is most intensive (Fedorov and Kapkov 2000).

Quantitative phytoplankton samples with a volume of 0.5 l were collected using bathometers at three sites: the middle, left and right banks. In the middle of the river, samples were taken from the surface, middle and bottom water layers; in the shallows, samples were taken from the surface water layer.

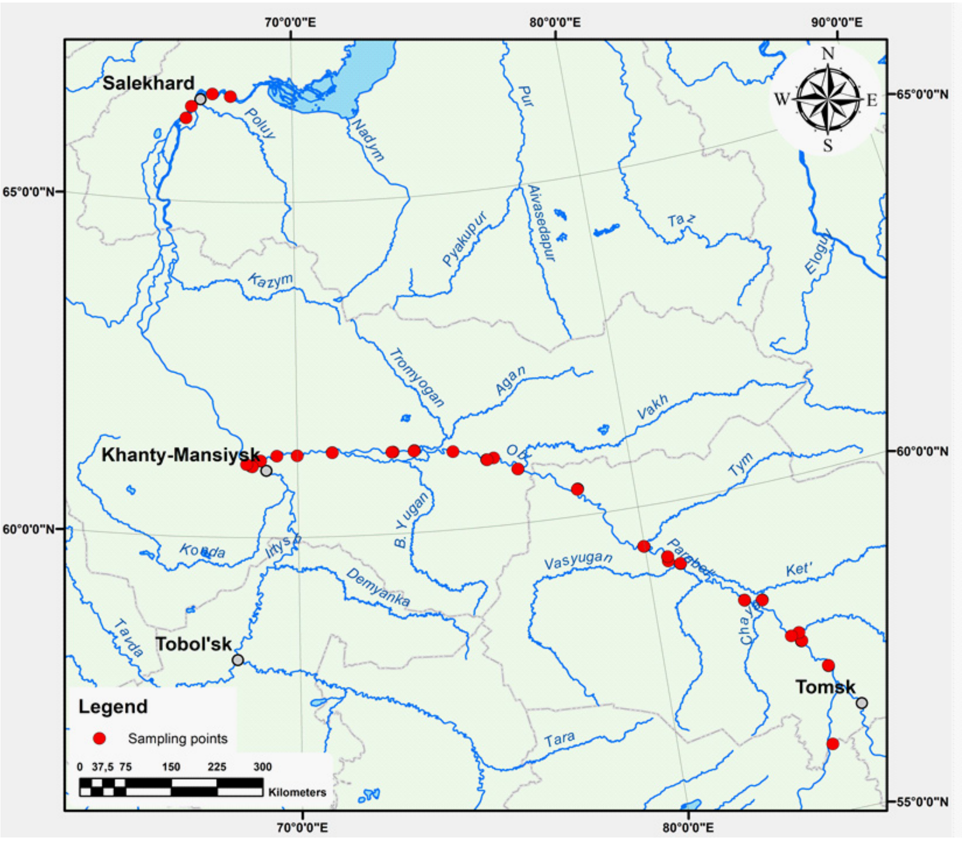

Figure 1. Location of phytoplankton sampling sites along the Ob River, summer 2019.

Phytoplankton samples were fixed with 4% formalin Lugol's solution, and sedimentary concentration was performed (10–14 days for 500-mL volume). The number of algal cells was counted in the Goryaev chamber with a volume of 0.9 mm^3 in duplicate using an Euler Professor 770T light microscope. The biomass was calculated using the counting weighing technique based on the number and volume of cells determined by the formulas of geometric similarity (Koltsova 1970).

The dominant species were identified with regard to biomass and numbers; those with numbers and biomass of at least 10% of the total were considered the dominant species (Korneva 2009). The dominant frequency (DF, %) was calculated using the formula:

$$DF = (n/N) \times 100 \,, \tag{1}$$

where n – the number of samples of dominant species; N – the total number of samples (Kozhova 1970).

The taxonomic list of phytoplankton was compiled with regard to modern systematic reports (Krakhmalny 2011; Voloshko 2017; Guiry and Guiry 2021). The trophic status and water quality class were assessed by the phytoplankton biomass (Oksiyuk et al. 1993).

To study the parameters of the phytoplankton alpha diversity in the Past (Paleontological Statistics Software for Education and Data Analysis) (Past 4) program, the Shannon and Margalef diversity indices, Simpson index of community evenness and dominance were calculated using the formulas:

– Simpson dominance index

$$D = \sum_i \left(\frac{ni}{n}\right)^2 \,, \tag{2}$$

where n is the total number of taxa and ni is the number of individuals of the i-th taxon.

– Simpson evenness index

$$1\text{-}D \,, \tag{3}$$

where D is the Simpson dominance index.

– Shannon index

$$H = -\sum_i \left(\frac{ni}{n}\right) \ln \left(\frac{ni}{n}\right) \,, \tag{4}$$

where n is the total number of taxa and ni is the number of individuals of the i-th taxon.

– Margalef index

$$(S - 1)/\ln(n)\,, \qquad (5)$$

where S is the number of taxa; n is the total number of taxa.
The data were statistically processed using Microsoft Excel.

Results and discussion

Based on 2019 results, 398 species and intraspecific taxa (IST) have been identified in phytoplankton of the Ob River, including nomenclatural species, from 8 divisions: Cyanoprokaryota – 52 taxa, Dinophyta – 9 taxa, Chrysophyta – 34 taxa, Xanthophyta – 15 taxa, Euglenophyta – 60 taxa, Bacillariophyta – 35 taxa, Chlorophyta – 170 taxa, Charophyta – 23 taxa.

In summer, the leading role in the formation of phytoplankton diversity belongs to green algae. Euglena algae and cyanoprokaryotes take the second and third places, respectively. The proportion of other divisions varies insignificantly (Fig. 2).

The predominance of green algae in phytoplankton is typical of other regulated rivers of Siberia: the Yenisei (Priimachenko et al. 1993), the Angara (Vorob'eva 1995), the Volga (Korneva 2009), and the Dnieper (Shcherbak 2000). This can be the general direction of changes in the phytoplankton structure, which occurs during regulation of large rivers.

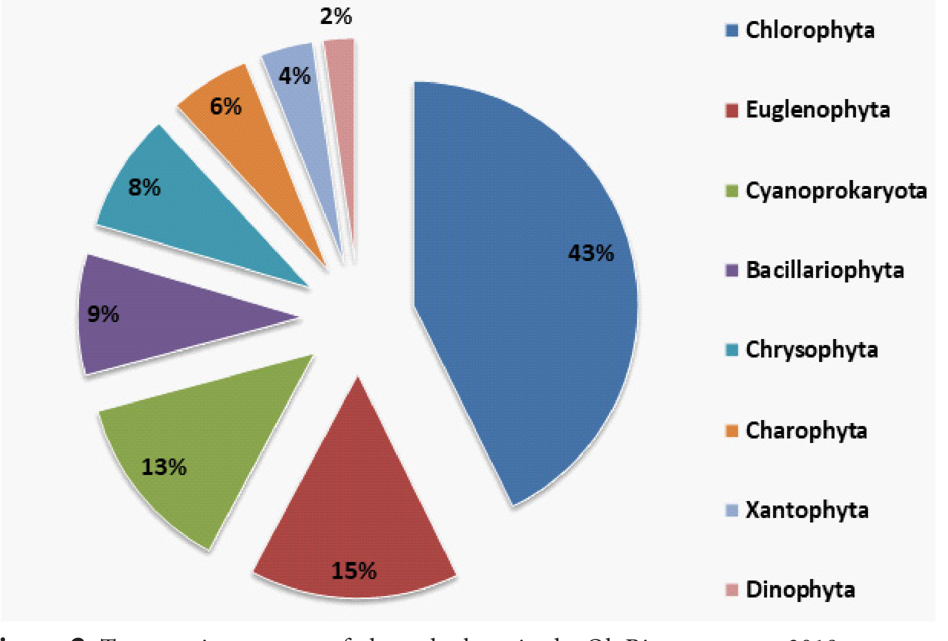

Figure 2. Taxonomic structure of phytoplankton in the Ob River, summer 2019.

Comparison of our data with the previous studies (Mitrofanova 2016; Mitrofanova 2019) showed changes in the taxonomic structure of phytoplankton in the Ob. Green, euglena algae and cyanoprokaryotes still prevail in the river phytoplankton, yet their proportion in the taxonomic structure has increased significantly. The proportion of green algae increased from 23 to 42%, that of euglena increased from 4.4 to 15%, and that of cyanoprokaryotes grew from 6.7 to 13%. Similar changes typical of phytoplankton of water bodies subject to anthropogenic eutrophication and pollution by easily oxidizing organic matter were found in the Irtysh (Bazhenova 2009), the Volga (Korneva 2009), and the Yenisei (Kozhevnikova 2001).

The middle reaches of the river showed the highest phytoplankton diversity (360 IST), and the lowest one was typical of its upper reaches (145 IST); in the lower reaches, 198 IST were found. This distribution pattern of phytoplankton diversity along the Ob differs from the data obtained at the end of the 20th century, when it significantly increased in the lower reaches of the Ob (mainly due to diatoms) (Naumenko 1995); however, it is similar to phytoplankton distribution in the Yenisei (Priimachenko, Bazhenova 1990). High phytoplankton diversity in the middle Ob is due to the dense hydrographic network, which is known to stimulate diversity (Korneva 2009). In addition, numerous shallow water bodies of the sor system serve as a floristic donor for the main channel of the river and have a pronounced effect on the plankton in the second half of summer (Kuksn 1970b).

The taxonomic structure of phytoplankton from different parts of the Ob varies significantly. Green algae prevail in phytoplankton throughout the studied watercourse; this is especially evident in its upper part. In the middle reaches of the river, the proportion of euglena algae and cyanoprokaryotes in the phytoplankton structure increases, but in the lower reaches, their role in the formation of the phytoplankton structure decreases (Fig. 3).

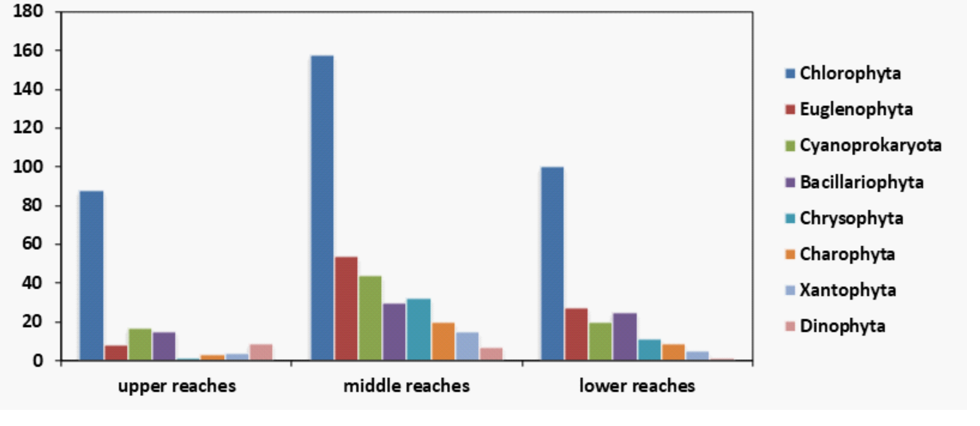

Figure 3. Taxonomic structure of phytoplankton in different parts of the Ob River, summer 2019

In phytoplankton studies, identification and analysis of the dominant species complex is of prime importance. In summer 2019, the dominant complex of phytoplankton in the Ob was composed of diatoms, green algae and cyanoprokaryotes, and its composition significantly differed depending on the identification method. In terms of numbers, the dominant complex contained 13 species, including 7 cyanoprokaryotes, 4 centric diatoms, and 2 green algae. In terms of biomass, the dominant complex composition was formed by 11 species: diatoms (9 species, including 3 centric species) and green algae (2 species) (Table 1).

The composition of the dominant complex of phytoplankton in different parts of the OB differs significantly. The richest dominant complex of the middle reaches accounts for 17 species. In numbers, it is dominated by cyanoprokaryotes (7 species), and in biomass, it shows prevalence of diatoms (8 species, including 3 centric species). Only in the middle reaches of the Ob, the dominants include 2 types of green algae.

In the upper and lower reaches of the river, the composition of the dominant complex of phytoplankton is much scarcer. In the upper reaches, in terms of numbers, it is dominated by cyanoprokaryotes (2 species) and centric diatoms (1 species), and in terms of biomass, the only dominant is centric diatoms. The dominant complex of phytoplankton in the lower reaches of the river is most even; it includes two species of centric diatoms of the genus *Aulacoseira*, in terms of both numbers and biomass.

Table 1. Dominant complex of phytoplankton in the Ob River, summer 2019

Part of the river	Dominant species	
	In numbers	In biomass
Upper reaches	*Aphanocapsa holsatica* *Aphanocapsa incerta* *Stephanodiscus hantzshii*	*Aulacoseira granulata* *Stephanodiscus hantzshii*
Middle reaches	*Aphanocapsa holsatica* *Aphanocapsa incerta* *Aphanocapsa planctonica* *Aphanocapsa delicatissima* *Chroococcus minimus* *Merismopedia minima* *Snowella lacustris* *Aulacoseira granulata* *Cyclotella* sp. *Stephanodiscus hantzshii* *Pediastrum duplex* *Nephrochlamys allanthoidea*	*Asterionella formosa* *Stephanodiscus hantzshii* *Cyclotella* sp. *Aulacoseira granulata* *Ulnaria ulna* *Cymbella* sp. *Synedra* sp. *Cymbella* sp. *Pediastrum duplex* *Nephrochlamys allanthoidea*
Lower reaches	*Aulacoseira granulata* *Aulacoseira* sp.	*Aulacoseira granulata* *Aulacoseira* sp.

The main dominant species in summer phytoplankton, as before (Mitrofanova 2016), are centric diatoms (Table 1). The maximum dominant frequency (DF) was found for *Aulacoseira granulata* (Ehr.) Simonsen, (DF in numbers of 76,74, DF in biomass of 79,10). A high dominant frequency (DF>20) in numbers is also indicated by small-celled non-heterocyst forms of cyanoprokaryotes *Aphanocapsa incerta* (Lemm.) Cronb. Et Komárek (55,80), *Aphanocapsa holsatica* (Lemm.) Cronb. Et Komárek (23,26), and the diatom *Aulacoseira* Thw. sp. (23,30). In other species, part of the dominant population complex in numbers, DF≤20.

According to the data of 2015 (Mitrofanova 2016), a significant contribution in the formation of the dominant complex by biomass was made by cyanoprokaryotes: *Dolichospermum flos-aquae* (Bréb.ex Born. etFlah.) Wacklin, Hoffmann et Komárek, *Leptolyngbya tenuis* (Gomont) Anagn. et Komárek, *Chroococcus minutus* (Kütz.) Näg., *Microcystis pulverea* (Wood) Forti, *Aphanizomenon flos-aquae* Ralfs ex Bornet et Flah., and *Snowella lacustris* (Chod.) Komárek et Hindak. In our studies, these species were not recorded in the composition of dominants either in biomass or in numbers (with the exception of *S. lacustris*); a high dominant frequency in numbers was characteristic of non-heterocyst forms of cyanoprokaryotes, of which 4 species belonged to the genus *Aphanocapsa* Näg.

Thus, the composition of the dominant complex of phytoplankton in the Ob exhibits significant interannual variability. The enrichment of the dominant composition due to cyanoprokaryotes, including non-heterocyst ones, can be observed in numerous rivers in Russia – in the basin of the Volga (Korneva 2015), the Irtysh (Successions..., 2010), the Angara (Kozhova, Basharova, 1984), the Yenisei (Kozhevnikov, 2001), and in other continents – the Parana rivers (South America) (O'Farrell, Izaguirre, Vinocur, 1996) and York (Virginia, USA) (Marshall 2009).

This process is typically observed at the final stages of oligo-eutrophic succession and indicates an increased trophic status of waters (Korneva 2015; Kornev and Glushchenko, 2020).

The dominant frequency of most species by biomass varied from 2.3 to 18.6% in all parts of the Ob, and only *Aulacoseira granulata* showed maximum DF of 79.1%.

Thus, identification of dominant phytoplankton species by numbers or biomass revealed a significant difference in the complex composition. Identification of the dominant phytoplankton species is one of the most serious problems in hydroecological studies. Most algologists identify dominant species by biomass, or compile a list of dominants in both numbers and biomass to make comparison. In recent years, a 10% level of total biomass or numbers was proposed as a criterion for including the species in the list of dominants (Korneva 2009), which quickly became widely used.

One of the fundamental biological concepts is the idea of greater metabolic activity of small organisms compared to large ones (Diatom algae 1974; Odum 1975; Aleev 1986). This idea was confirmed by various studies. For example, in the second half of the 20th century, autoradiography revealed that the intensity of photosynthesis (specific production per unit of biomass) decreases when the cell volume grows

(Gutelmakher 1974). This was evidenced by the study of phytoplankton in the Yenisei on the example of different-sized cells of centric diatoms of the genera *Aulacoseira* Thw. and *Stephanodiscus* Ehr. (Bazhenova 1992). To confirm the hypothesis proposed by A.I. Proshkina-Lavrenko (Diatoms 1974) on the decrease in metabolic activity with an increase in the volume of the shell of diatoms, it was shown that an increased size decreases the shell perforation of centric (Genkal 1993) and pennate (Kulikovsky 2016) diatoms.

Thus, small-celled organisms exhibit the highest productivity at their trophic level; therefore, their numbers and not biomass should be considered to identify dominant phytoplankton species. A significant contribution to the substantiation of the considered idea was made by T.M. Mikheeva (1992), who suggested identification of dominant phytoplankton species by numbers in water bodies subject to eutrophication. In our study, the dominant phytoplankton complex in the Ob River formed with regard to the number of species indicates significant changes in the structural parameters of phytoplankton and is much more informative than that formed with regard to biomass, which includes numerous species with low DF.

Indicators of phytoplankton abundance in the studied watercourse of the Ob River show significant heterogeneity caused by the discharge of water from the Novosibirsk reservoir, various hydrological and climatic conditions, and the effect of tributaries. The numbers and biomass of phytoplankton in the river significantly varied in the range of 3.98–20.71 mln cells/l (on average 9.1 ± 2.6 mln cells/l) and 2.5–11.22 g/m^3 (on average 5.7 ± 0.34 g/m^3), respectively. The maximum numbers of phytoplankton, which is predominantly made up of cyanoprokaryotes (up to 80%) and green algae, were recorded in the upper reaches of the Ob near Melnikovo (Fig. 4).

In this part of the Ob located below the dam of the Novosibirsk hydroelectric power station, phytoplankton comprises small-cell species of cyanoprokaryotes (*Aphanocapsa incerta*), diatoms (species of the genera *Stephanodiscus* and *Cyclotella* (Kütz.) Bréb.), and green algae (*Monoraphidium contortum* (Thur.) Kom.-Legn.). High numbers of phytoplanktonan in this part is likely due to the impact of the Novosibirsk reservoir, where an intense vegetation of cyanoprokaryotes and green algae was recorded in summer (Mikhailov and Bazhenova 2019). Centric diatoms play a crucial role in the formation of phytoplankton biomass in the upper reaches of the river, and their proportion attains 81.46%.

In the middle reaches of the Ob, the numbers and biomass of phytoplankton gradually decrease and vary in wider ranges. The numbers of phytoplankton ranged from 4.66 to 16.31 mln cells/l (on average 9.03 ± 0.61 mln cells/l), and biomass varied from 2.5 to 11.2 g/m^3 (on average 5.34 ± 0.37 g/m^3).

The maximum phytoplankton numbers in the middle reaches of the river were recorded below the Tym confluence. The dominants in this area were cyanoprokaryotes *Aphanocapsa incerta* (7.4 mln cells/l), *A. holsatica* (4.0 mln cells/l), and *A. planctonica* (G.M. Smith) Komáreket Anagn. (5.8 mln cells/l), as well as centric diatoms of the genera *Aulacoseira* (2.57 mln cells/l), *Cyclotella* (1.32 mln cells/l), and *Stephanodiscus* (0.88 mln cells/l).

Cyanoprokaryotes, green algae and diatoms made up the largest proportion (98%) of the total plankton abundance in the middle reaches of the Ob. Diatoms play the most important role in the formation of biomass and make up to 88% of the total biomass. Centric algae of the genera *Aulacoseira*, *Stephanodiscus*, and *Cyclotella* are most abundant.

After the Irtysh confluence (10 km below the Irtysh mouth), the numbers and biomass of phytoplankton increased significantly (Fig. 4). The species of the genus *Aulacoseira* (10.2 mln cells/l) and *Aphanocapsa incerta* (6.0 mln cells/l) prevailed. The high level of numbers and biomass of phytoplankton in this part of the river are due to the "edge effect" or ecotone that occurs when water masses of different chemical properties and origin confluence (Odum 1975). A similar phenomenon is known for the Dnepr (Primaichenko 1981), the Yenisei (Primaichenko et al. 1993) and was previously observed for the Ob (Naumenko 1996).

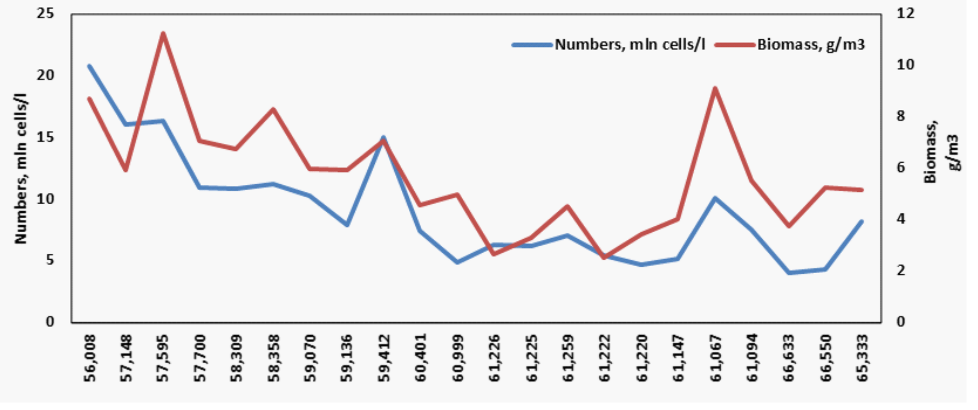

Figure 4. Dynamics in numbers and biomass of phytoplankton in the studied watercourse of the Ob River, summer 2019.

The lowest phytoplankton numbers were recorded in the lower reaches of the Ob, near Salekhard: the numbers ranged from 3.98 to 8.14 mln cells/l, and the biomass varied from 3.74 to 5.23 g/m^3.

Along the entire length of the Ob, excluding the area near Salekhard, the numbers and biomass of phytoplankton in summer 2019 were significantly higher than those in the previous studies conducted in July 1999 (Mitrofanova 2008) and during the open water period in 2001 (Mitrofanova 2015).

In July 1999, phytoplankton numbers were observed to significantly increase in the middle reaches of the river. For example, in the vicinity of villages Kargasok, Kolpashevo, and Aleksandrovskoe, the maximum numbers and biomass were 0.84 mln cells/l and 0.76 g/m^3, respectively (Mitrofanova 2008), and these values were even higher in July 2019: from 7.4 mln cells/l and 4.55 g/m^3 (Aleksandrovskoe) up to 10.8 mln cells/l and 6.48 g/m^3 (Kolpashevo).

Phytoplankton abundance in the lower reaches increased significantly compared to that observed at the end of the 20th century (Mitrofanova 2016) and in 2015 (Mitrofanova 2019).

The trophic status of the Ob in summer 2019 corresponded to the eutrophic category of water in its studied watercourse. The water quality varied from class 3 (satisfactory purity) to class 4 (contaminated) (Table 2).

Table 2. Trophic status of the Ob River in 1993–2015 (Mitrofanova 2008, 2016; Mitrofanova 2015, 2019) and in summer 2019

Part of the river	Literature data		July–August 2019		
	Biomass, g/m^3	Trophic status	Biomass, g/m^3	Trophic status	Water quality class
Upper reaches	1.10 (1993) 0.80 (2004)	Mesotrophic	8.71±0.97	Eutrophic	4 – contaminated
Middle reaches	0.20–3.20 (1999)	Oligo-, meso-, eutrophic	5.99±0.57	Eutrophic	4 – contaminated
Lower reaches	0.07–1.30 (1993–1994) 0.20±0.06 (2015)	Oligo-, mesotrophic	4.71±0.89	Eutrophic	3 – of satisfactory purity

The trophic status of the Ob River was found to increase as compared to that observed in the previous studies of phytoplankton in 1993–2015 (Mitrofanova 2008, 2016; Mitrofanova 2015, 2019).

The analysis of the phytoplankton alpha diversity showed that the most complex structure of the community could be observed in the middle reaches of the Ob. High values of the Shannon index, which indicates the complexity of the community structure (Geography and Monitoring... 2002, Barinova et al. 2006), were found in the upper parts of the middle reaches of the Ob, near Nikolskoe village, and attained their maximum in the part of the river with coordinates 61°13'/69°59', which is slightly higher than Khanty-Mansiysk. The lowest values of the Shannon index were recorded in the lower reaches of the river. The Shannon index calculated by numbers varies in the range of 2.03–3.39, averaging 2.82 ± 0.07, which indicates the average complexity of the phytoplankton structure (Table 3).

Compared with the literature data (Mitrofanova 2008), the phytoplankton diversity in the Ob has not changed significantly. In the previous studies (1993–2004), the Shannon index by numbers and biomass varied in the ranges of 2.13–3.31 and 2.04–3.00, respectively, which indicates the average complexity of the phytoplankton structure.

Table 3. Diversity indices of phytoplankton in the Ob River, July 2019

°N (DD)	°E (DD)	Sampling point	Shannon index	Margalef index	Simpson index of evenness	Simpson index of dominance
56.008	84.003	Melnikovo	2.61	5.99	0.85	0.15
57.148	84.351	Nikolskoe	3.09	6.83	0.91	0.08
57.595	83.795	Molchanovo	3.09	6.90	0.90	0.08
57.700	83.555	Mogochino	3.07	6.67	0.90	0.09
58.309	82.977	Kolpashevo	2.87	6.35	0.89	0.11
58.358	82.498	Below the Chaya confluence	2.85	6.90	0.86	0.14
59.070	80.931	Kargasok	2.83	6.65	0.86	0.14
59.136	80.604	Below the Vasyugan confluence	3.02	5.93	0.91	0.09
59.412	79.982	Below the r. Tym confluence	2.94	6.90	0.89	0.11
60.401	78.327	Above Alexandrovskoe	2.84	5.82	0.88	0.12
60.999	75.745	Below Megion	3.07	5.78	0.92	0.08
61.226	73.570	Above Surgut	2.73	5.84	0.88	0.12
61.225	72.900	Below Surgut	3.09	6.01	0.92	0.08
61.259	71.071	Below Sytomino	3.01	6.09	0.91	0.09
61.222	69.998	-	3.39	6.40	0.95	0.05
61.220	69.379	-	3.13	5.62	0.92	0.08
61.147	68.873	-	2.46	5.80	0.75	0.25
61.067	68.598	10 km below the r. Irtysh mouth	2.03	5.75	0.64	0.36
61.094	68.466	20 km below the r. Irtysh mouth	2.63	5.94	0.85	0.15
66.633	66.460	Salekhard	2.74	5.55	0.85	0.15
66.550	66.466	Salekhard	2.31	4.83	0.81	0.19
65.333	66.450	Salekhard	2.08	4.44	0.78	0.22
Average			2.82±0.07	6.05±0.13	0.94±0.07	0.14±0.01

The Margalef index indicates the density or diversity of species in a certain area; the higher the index value, the greater the species diversity in this area. According to the Margalef index, the highest phytoplankton diversity is characteristic of the middle reaches of the Ob. The maximum index values were recorded near Molchanovo village and below the confluence of the Chaya and the Tym, which indicates enriched phytoplankton composition in the Ob due to these tributaries. The minimum values of the Margalefan index were recorded in the lower reaches of the Ob near Salekhard.

The Simpson dominance index was low and ranged from 0.05 to 0.36 then gradually increased in the lower reaches of the Ob (Table 3). Phytoplankton in the middle reaches of the river showed minimum values of the dominance index, which is consistent with the values of the Shannon and Margalef indices that indicate the most complex phytoplankton structure in the middle reaches of the Ob. The maximum dominance index was recorded 10 km below the Irtysh mouth with phytoplankton dominated by cyanoprokaryotes and centric diatoms (Bazhenova and Barsukova, 2020). No significant increase in the dominance index (up to 1) was observed in sampling sites, which corresponds to populations with unexpressed dominants and indicates the average complexity of the phytoplankton structure.

The Simpson evenness index in the Ob varied within relatively narrow ranges (on average 0.94 ± 0.07); the narrowest ranges of (0.86–0.95) were characteristic of the phytoplankton in the middle reaches. The minimum evenness index (0.64) was recorded below the Irtysh mouth, which is consistent with the high dominance index in this part of the river and confirms a significant impact of the Irtysh on the phytoplankton in the Ob. High values of this index indicate evenness of the phytoplankton structure in the Ob and the absence of evident dominants, which is consistent with the dominance index values.

However, in spite of the revealed changes in the taxonomic structure, the complex composition enriched with cyanoprokaryotes, including non-heterocyst ones, and increased phytoplankton abundance, biodiversity indices and their dynamics in the watercourse indicate a high species diversity, high evenness and average complexity of the phytoplankton structure. All of the above suggests that the Ob ecosystem is stable, and it is supported by active self-purification processes due to the diverse and abundant phytoplankton.

Conclusion

1. In summer 2019, 398 species and intraspecific taxa of algae, including nomenclatural species, from 8 divisions were identified in phytoplankton of the Ob River. The species diversity was represented mainly by green (42.71%) and euglena (15.10%) algae, and cyanoprokaryotes (13.01%), the proportion of other divisions ranged from 2.26 to 8.79%. The taxonomic phytoplankton structure exhibited an increased proportion of these divisions compared to the data obtained in the previous studies.

2. The dominant phytoplankton complex (in numbers) was represented by 7 species of cyanoprokaryotes, 4 species of centric diatoms, and 2 species of green algae. The maximum dominance frequency (DF=76.74) was found for *Aulacoseira granulata*, and high dominance frequency (DF = 23.26–55.80) was recorded for non-heterocyst colonial forms of cyanoprokaryotes of the genus *Aphanocapsa*.

3. The composition of the dominant phytoplankton complex in different parts of the river differs significantly. In the upper reaches, the dominants include 2 species of heterocyst forms of cyanoprokaryotes (*Aphanocapsa holsatica*, *A. incerta*) and 1 species of centric diatoms (*Stephanodiscus hantzshii*). The most diverse dominant complex of the middle course of the river was represented by cyanoprokaryotes (7 species), centric diatoms (3 species), and green algae (2 species). The least diverse dominant complex of the lower reaches of the river included 2 species of the genus *Aulacoseira*.

4. The abundance of phytoplankton in summer gradually decreased in the lower reaches of the river; its maximum was recorded in the upper reaches of the river (20.7 million cells/l), and its minimum was recorded in the lower reaches of the river near Salekhard (3.98 mln cells/l).

5. The phytoplankton biomass, similar to numbers, also decreased in the lower reaches of the river. Below the confluence of the Irtysh and the Ob, the "edge effect" was observed at the confluence of water masses of different nature and chemical properties. There was a significant increase in the phytoplankton numbers (from 7.5 to 10 mln cells/l) and biomass (5.5–9.1 g/m^3).

6. The trophic status of the Ob River in summer 2019 in the studied watercourse corresponded to the eutrophic category, which is higher than that in the previous studies (1993–2015). The water quality class varied from class 3 (satisfactory purity) to class 4 (contaminated).

7. The Shannon index varies in the range of 2.03–3.39 (on average 2.82 ± 0.07) and indicates the average complexity of the phytoplankton composition in the Ob. The Margalef diversity index ranges from 4.44 to 6.90 (on average 6.05 ± 0.13); its maximum values are recorded in the middle reaches of the Ob River. The Simpson dominance index is low throughout the studied watercourse of the Ob and varies in the range of 0.05–0.36 gradually increasing in its lower reaches. The Simpson evenness index of (0.94 ± 0.07) indicates the absence of evident phytoplankton dominants.

Biodiversity indices show high species diversity and average complexity of the phytoplankton structure in the Ob. The values of the indices correspond to those obtained in the previous studies (1993–2004).

8. In total, the observed changes in the structural parameters of phytoplankton – taxonomic structure, dominant complex composition enriched due to cyanoprokaryotes, including non-heterocyst ones, and increased phytoplankton abundance throughout the entire watercourse of the Ob – indicate an increasing eutrophication of the ecosystem of the Ob River caused by increased anthropogenic impact and climatic changes.

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