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Articles

Phytoplankton of the Ket River (Tomsk Region)

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The characteristic of the phytoplankton of the Ket River (Tomsk region) is given based on the results of studies in July 2019 and 2021. The species composition and taxonomic structure of phytoplankton were established; a complex of dominant species was identified, and the abundance, biomass and biodiversity indices of phytoplanktocenosis were calculated. Green algae (Chlorophyta) and significant number of euglenids (Euglenophyta) form the basis of phytoplankton species richness. The dominant complex is formed by centric diatoms and cyanoprokaryotes. Biodiversity indices indicate high species richness, average complexity and balanced structure of phytoplanktocenosis. Trophic status of the river corresponds to eutrophic category of waters, the water quality corresponds to class 3 "satisfactory purity".

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Algae, biodiversity, dominant species, taxonomic structure, trophic status, water quality, West Siberia

Introduction

The Ket is a large right tributary of the middle course of the Ob river, flowing into it with two which are the Togur Ket (located downstream from Kolpashevo) and the Kopylovskaya Ket (located 2246 km from the mouth of the Ob), flowing along the Ob to the village Narym. The river is a plain stream one, and its source is located in the swamps of the Ob-Yenisei watershed. It flows through the West Siberian Plain, through the territories of Krasnoyarsk Krai and the Tomsk Region. The river is 1621 km long, and half of it (805 km) flows through the Tomsk Region. The drainage basin (94200 km^2) is covered with deciduous and coniferous forests, and the average annual flow volume is 560 m^3/s or 17.7 km^3. A high water period lasts from May to August. The river freezes in late October – early November and breaks up in late April – early May. The riverbed is characterized by a high degree of meandering, the flow velocity rarely exceeds 1 m/s (Resources of surface … 1967; Domanitsky et al. 1971; Evseeva 2001).

Conservation of wetlands in West Siberia, which are of great importance in maintaining biodiversity and performing their resource and socio-economic functions (Bulatov 2009), has become a significantly more acute problem in recent years due to the high level of anthropogenic impact in the Ob-Irtysh basin and global climate change (Puzanov et al. 2017). The current situation determines the need to study and assess the current state of water bodies in the region using data on their biocenoses development and taking into account natural features of drainage basins. Phytoplankton, which occupies first level of trophic structure, quickly reacts to anthropogenic and other impacts. It is the most important indicator in assessing ecological state of water bodies (Abakumov 1977; Bazhenova 2005). Phytoplankton structural indicators play a significant role in this process, especially in the context of ecological modifications. These indicators are species composition, taxonomic structure, abundance, biomass, etc. (Abakumov 1991). In order to preserve and restore aquatic ecosystems, the European Water Framework Directive proposes to assess the ecological status of reservoirs by structural indicators of phytoplankton (Directive of the European ... 2000).

The aim of the work is to assess the ecological state, trophic status and water quality of the Ket River by phytoplankton structural indicators.

Material and methods

The study was based on the materials obtained from the analyzed samples of phytoplankton that were taken on July 15, 2019 and July 12, 2021 in the mouth of the Ket (Kopylovskaya Ket) 2 km above the village Narym. Coordinates of the sampling site: in 2019 – 58°53'44.5"N, 81°33'29.9"E; in 2021 – 58°53'25.5"N, 81°34'57.0"E. Quantitative sampling of phytoplankton in the amount of 0.5 ^{dm3} was carried out from the surface layer of water (0-20 cm) using a barometer. The samples were fixed using 40% formalin mixed with Lugol solution and concentrated by sedimentary method. Qualitative samples were obtained by integrating quantitative ones. The samples were processed by conventional methods (Fedorov 1979). The number of algae cells was taken into account in the Goryaev counting chamber in duplicate. Biomass was calculated by the counting by weighing method, based on the number and volume of cells that was determined via geometric similarity formulas (Koltsova 1970). The dominant species included species whose number was at least 10% of the total (Korneva 2015). Trophic status and water quality were assessed by phytoplankton biomass (Oksiyuk et al. 1993).

During sampling, the flow velocity, depth, water temperature in the surface layer, water Secchi disk transparency, electrical conductivity of water, pH, BOD_5, total mineralization, O_2 and CO_2 content were measured.

Species identification was carried out on the Euler Professor 770T light microscope using modern determinants, monographs and summaries.

The taxonomic list of algae was compiled taking into account modern nomenclature transformations. Dinophyta (Krachmalnyi 2011), Chrysophyta and Xanthophyta (Voloshko 2017) were allocated to independent divisions. Species names were specified according to Algaebase international database (Guiry and Guiry 2022).

Taxonomic structure of phytoplankton was analyzed using methods of comparative floristics (Schmidt 1980).

Ecological and geographical description of the identified species was based on the materials of determinants and individual publications (Barinova et al. 2006, 2019).

When studying phytoplanktocenosis alpha diversity parameters in the Paleontological Statistics Software for Education and Data Analysis (Past 4), the indices of Shannon (**H**) and Margalef (**d**) diversity, Simpson dominance (**D**) were calculated using the following formulas:

$$D = \sum_i \left(\frac{ni}{n}\right)^2, (1)$$

Figure 1. *Simpson dominance index*

where **n** is the total number of taxa;

ni is the number of individuals of the **i-** taxon;

$$\mathrm{H} = -\sum_i \left(\frac{ni}{n}\right) ln\left(\frac{ni}{n}\right), (2)$$

Figure 2. *Shannon index (H)*

where **n** is the total number of taxa;

ni is the number of individuals of the **i-** taxon;

$$\mathrm{d} = (S - 1)/ln(n), (3)$$

Figure 3. *Margalef index*

where **S** is the number of taxa;

n is the size of community.

The Margalef index reflects the species richness in a certain area, its calculation uses an absolute value (abundance), which makes it extremely sensitive to the sample size. The Shannon index characterizes the diversity and evenness in the community structure. The Simpson index shows the degree of dominance of certain species in the community structure (Schitikov et al. 2011).

Microsoft Excel program was used for statistical data processing.

Results

The Ket water was slightly mineralized (51.0–79.3 mg/dm^3), water electrical conductivity was relatively low (108.4–165.0 ms/cm), active reaction of the medium varied from neutral to slightly alkaline one (7.30–7.92). Surface layer temperature varied between 21.0–22.0 °C, water transparency was low (0.45 m), the flow velocity reached 0.44 m/s, and the depth of the river at the sampling points was 1.2 m. The oxygen content was sufficient (4.56–8.36 ppm), the CO_2 content ranged widely from 430 ppm in 2019 to 4086 ppm in 2021. By the value of BOD_5 (1.28 mg O/dm^3), the river belongs to the class of pure waters (Guseva et al. 2000).

To date, 209 species and intraspecific taxa from 8 divisions are identified in the phytoplankton of the Ket River, including the species name-bearing type: Cyanoprokaryota – 19, Dinophyta – 7, Xanthophyta – 6, Chrysophyta – 9, Euglenophyta – 37, Bacillariophyta – 29, Chlorophyta – 100, Charophyta – 2 (Table 1, Application-Link: http://journal.asu.ru/biol/article/view/12557/10407)

Phylum	Class	Number of				
		Orders	Families	Genera	Species	Intraspecific taxa
Cyanoprokaryota	Cyanophyceae	4	6	12	19	19
Dinophyta	Dinophyceae	2	4	5	7	7
Xanthophyta	Xanthophyceae	1	2	3	5	5
	Eustigmatophyceae	1	1	1	1	1
Chrysophyta	Chrysophyceae	1	2	4	9	9
Euglenophyta	Euglenophyceae	1	2	5	30	37
Bacillariophyta	Coscinodiscophyceae	2	2	2	4	4
	Mediophyceae	2	2	3	4	4
	Bacillariophyceae	9	12	16	21	21
Chlorophyta	Chlorophyceae	2	13	32	64	67
	Trebouxiophyceae	2	4	17	32	33
Charophyta	Zygnematophyceae	1	1	1	2	2
Total		28	51	101	198	209

Table 1. *Taxonomic structure of summer phytoplankton of the Ket River, 2019–2021*

Green algae represented the basis of the phytoplankton species richness, forming about half (47.85%) of the taxonomic composition, significantly inferior to them were euglenids (17.70%), diatoms (13.88%) and cyanoprokaryotes (9.09%). Other divisions of algae did not play significant role in forming the Ket phytoplankton species richness.

Most representatives of green algae (Chlorophyta) belonged to a group of small-celled species (*Monoraphidium* Kom.-Legn., *Raphidocelis* Hind., *Siderocelis* (Naum.) Fott, *Coenocystis* Korsch., *Coenococcus* Korsch., *Pseudodidymocystis* Hegew. et Deason, *Tetrastrum* Chod. etc.). In terms of species richness, the *Desmodesmus* genus (Chod.) An, Friedl et Hegew. (12 intraspecific taxa) standed out among green algae.

The Ket River diatoms composition was formed by two ecological groups – true planktonic and accidental planktonic species. The former created the largest proportion of phytoplankton abundance and the basis of its biomass. Representatives of centric diatoms predominated, which were species of the genera *Aulacoseira* Thw., *Stephanodiscus* Ehr., *Cyclotella* (Kütz.) Bréb., less frequently there are widespread species of pennate diatoms – *Asterionella formosa* Hass., *Diatoma tenuis* Ag., *Nitzschia holsatica* Hust., *Ulnaria acus* (Kütz.) Aboal.

The species richness of the Ket diatoms is caused mostly by diversity of accidental planktonic species of diatoms entering deep water layers with turbulent water flow via phytobenthos and periphyton. These include widespread species from the genera *Eucocconeis* Ehr., *Encyonema* Kütz., *Gomphonema* Ehr., *Navicula* Bory, *Nitzschia* Hass., *Surirella* Turp. and others . Abundance of this ecological group of diatoms is low, which is due to low flow rate of the Ket in summer.

The genus *Trachelomonas* Ehr. (19 intraspecific taxa) had the maximum species richness among the euglenids of the Ket, and the most common species were *Trachelomonas volvocinopsis* Swir. and *T. volvocina* (Ehr.) Ehr. Other genera of euglenids were represented by a small number of intraspecific taxa *Phacus* Duj. – 7, *Euglena* Ehr. – 6, *Lepocinclis* Perty – 3, *Strombomonas* Defl. – 2.

Cyanoprokaryotes were represented by 19 intraspecific taxa. A characteristic feature here was the presence, and in some cases, intensive vegetation of small-celled, non-heterocyst cyanoprokaryotes *Aphanocapsa incerta* (Lemm.) Cronb et Komárek, *Chroococcus minimus* (Keissl.) Lemm., *Ch. minor* (Kütz.) Näg. In summer 2021, *Dolichospermum scheremetieviae* (Elenkin) Wacklin, Hoffm. et Kom. dominated the river; its abundance reached 1.08 million cells/dm^3 and accounted for 42.52% of the total phytoplankton abundance. Trichomes of *Leptolyngbya foveolarum* (Gomont) Anagn. et Komárek were quite offen found in plankton.

As for the Chrysophyta, *Chrysococcus biporus* Skuja and *Dinobryon divergens* Imh. were most often found in the Ket plankton. The Xantophyta, Charophyta and Dinophyta were represented by a small number of algae species and varieties widely distributed in the plankton of water bodies in Western Siberia.

Analysis of the Ket phytoplankton taxonomic spectrum indicated the leading position of green algae and euglenids, occupying 1st, 2nd and 3rd rank places at all levels, from classes to genera. At the level of classes, orders and families, green algae occupied the first place in the phytoplankton taxonomic spectrum, but the gap between them and euglenids is gradually decreasing in the direction from class to family, and at the level of genera, euglenids are already in the first place (Tables 2, 3).

Class	Number of		Order	Number of	
	species	intraspecific taxa		species	intraspecific taxa
Chlorophyceae	64 (1)	67 (1)	Sphaeropleales	56 (1)	59 (1)
Euglenophyceae	30 (3)	37 (2)	Euglenales	30(2-3)	37 (2)
Trebouxiophyceae	32 (2)	33 (3)	Chlorellales	29(2-3)	30 (3)
Bacillariophyceae	21 (4)	21 (4)	Chlamydomonadales	8 (4)	8 (4)
Cyanophyceae	19 (5)	19 (5)	Chromulinales	7 (5-6)	7 (5-6)
Chrysophyceae	9 (6)	9 (6)	Nostocales	7 (5-6)	7 (5-6)
Dinophyceae	7 (7)	7 (7)	Peridiniales	6 (7-8)	6 (7-8)
Xanthophyceae	5 (8)	5 (8)	Synechococcales	6 (7-8)	6 (7-8)
Mediophyceae	4(9-10)	4 (9-10)	Mischococcales	5 (9)	5 (9)
Coscinodiscophyceae	4(9-10)	4 (9-10)			
Total	195	206	Total	154	165
% of the total number of taxa	98.48	98.56	% of the total number of taxa	73.68	78.95

Table 2. *Taxonomic spectrum of the leading classes and orders of summer phytoplankton of the Ket River (rank position is given in parentheses)*

Family	Number of		Genus	Number of	
	species	intraspecific taxa		species	intraspecific taxa
Scenedesmaceae	29 (1)	31 (1)	Trachelomonas	13 (1)	19 (1)
Euglenaceae	21 (2)	27 (2)	Desmodesmus	10 (2)	12 (2)
Oocystaceae	15 (3)	15 (3)	Phacus	7 (3)	7 (3)
Chlorellaceae	12 (5)	13 (4-5)	Euglena	6 (4-6)	6 (4-6)
Selenastraceae	13 (4)	13 (4-5)	Monoraphidium	6 (4-6)	6 (4-6)
Phacaceae	10 (6)	10 (6)	Scenedesmus	6 (4-6)	6 (4-6)
Hydrodictyaceae	6 (7)	7 (7)	Lagerheimia	5 (7)	5 (7)
Aphanizomenonaceae	5 (8)	5 (8)	Oocystis	4 (8)	4 (8)

Dinobryaceae	4(9-10)	4 (9-10)			
Sciadiaceae	4(9-10)	4 (9-10)			
Total	119	129	Total	57	65
% of the total number of taxa	56.94	61.72	% of the total number of taxa	27.27	31.10

Table 3. *Taxonomic spectrum of the leading families and genera of summer phytoplankton of the Ket River (rank position is given in parentheses)*

Diatoms, which usually dominate the plankton of rivers, occupied a modest place in the Ket phytoplankton taxonomic spectrum. Their participation was noticeable only at the class level, where diatoms of the Bacillariophyceae class occupied the 4th rank.

The participation of cyanoprokaryotes in the taxonomic spectrum was also hardly noticeable. At the class level, they followed diatoms. At the level of orders and families, their status gradually decreased. At the level of genera, exclusively euglenids and green algae dominated the phytoplankton taxonomic spectrum of the Ket River.

The ecological and geographical description of the identified algae species was very diverse. The majority of the found species (over 50%) had a known relation to their habitat (88.99% of the total number of intraspecific taxa found), water saprobity (74.16%), geographical distribution (68.42%), about half of the found species were indicators of salinity (45.45%), which allows correctly analysing the ratio of those or other environmental groups to the specified indicators. The pH ratio of the aquatic environment (so-called acidophilicity) is known only for 42 identified intraspecific taxa (20.10%), therefore it was not possible to characterize the river phytoplankton in this regard.

More than a third of the found species (37.10%) were truly planktonic inhabitants. The same proportion of species were able to inhabit both plankton and benthos (36.02%), and also occurred in periphyton (15.59%). There are few typical inhabitants of benthos (13 infraspecific taxa), and all of them belong to diatoms. Several species (9 intraspecific taxa) can inhabit both water and soil.

According to the Kolbe's classification, most of the species were indifferent to water salinity (77.42% of the number of species with known halobility), and smaller parts were halophiles (11.83%) and halophobes (4.30%). A small number of halobility indicators belonged to meso- and oligohalobes (6 intraspecific taxa). In terms of geographical distribution, most of the found species belonged to cosmopolitans (76.92% of the number of species with a known geographical distribution), boreal and circumboreal species made up to 5.59%, inhabitants of the holarctic region – 16.78%, and there was one of arctoalpin species (*Dinobryon suecicum* Lemm.).

Species that indicate saprobity index formed a significant part (74.16%) of the identified species. β-mesosaprobes predominated among them (49.68% of the total number of species with known saprobity). There were few inhabitants of clean waters - oligo- and xenosaprobes (12.26%), and a small part of the indicator species (3.87%) were inhabitants of dirty waters. A high proportion (33.55%) were indicators of saprobity transition zones – from clean to dirty (o-β, β-o, o-α, α-o, o-m).

The total abundance of summer phytoplankton in the mouth of the Ket varied widely during the years of research. Cyanoprokaryotes, green algae and diatoms make the main contribution to its formation. Representatives of other divisions formed a small proportion of the total phytoplankton abundance, ranging from 0.14 to 4.33%. The most significant role among them is played by euglenids (Table 4).

Month, year	Total abundance million cells/dm3	Total biomass, g/m3	Abundance, % / biomass,%				
			Cyanoprokaryota	Bacillariophyta	Euglenophyta	Chlorophyta	Other
July, 2019	7,13±0,05	2,49±0,10	18.23/0.15	30.71/54.38	1.40/6.47	49.10/27.36	0.56/11.62

July, 2021	2,54±0,01	2,60±0,11	42.52/25.39	21.65/55.24	4.33/14.31	29.92/4.62	1.58/0.44

Table 4. *Abundance and biomass of summer phytoplankton at the mouth of the Ket River*

The maximum phytoplankton abundance was observed in July 2019. It was due to intensive vegetation of the centric diatom *Aulacoseira sp.* (up to 1.72 million cells/dm^3) and small-cell non-heterocyst cyanoprokaryotes *Aphanocapsa incerta* (up to 1.0 million cells/dm^3), forming a dominant phytoplankton complex.

In summer of 2021, the phytoplankton abundance was almost 3 times lower than in 2019, which was mainly caused by a decrease in the vegetation of *Aulacoseira sp.* (100 thousand cells/ dm^3). There had been changes in the dominant species and among cyanoprokaryotes. Instead of *Aphanocapsa incerta*, *Dolichospermum scheremetieviae* became the only dominant phytoplankton (up to 1.08 million cells/dm^3).

Diatoms formed about a third (21.65–30.71%) of the total phytoplankton abundance. They play the most significant role in forming the total phytoplankton biomass (54.38–55.24%).

The contribution of green algae and cyanoprokaryotes to the total abundance of phytoplankton in the Ket differed markedly over the years of research. In 2019, intensive vegetation of small-celled green algae (*Monoraphidium contortum* (Thur.) Kom.-Legn., *Pseudodidymocystis inconspicua* (Korsch.) Hind., *Stauridium tetras* (Ehr.) Hegew., species of the genera *Desmodesmus, Scenedesmus* Meyen) was the reason for their largest abundance. In 2021, vegetation of green algae noticeably decreased, and cyanoprokaryotes took the leading positions in terms of abundance. Dominant *Dolichospermum scheremetieviae* had a larger cell size than 2019 dominant *Aphanocapsa incerta*. That was the reason why the importance of cyanoprokaryotes in the creation of total phytoplankton biomass in 2021 markedly increased, while the role of green algae, on the contrary, decreased. The share of green algae in the total phytoplankton biomass is insignificant and even lower than the contribution of the found species of euglenids that differ in large sizes (see Table 4). This is due to the predominance of small-celled species.

Parameters of the alpha diversity of the Ket phytoplanktocenosis have rather high metrics and differ significantly by the years of research (Table 5).

Year	Shannon index	Margalef index	Simpson index
2019	3.06	6.20	0.09
2021	2.47	4.10	0.20

Table 5. *Biodiversity indices of the Ket River summer phytoplanktocenosis*

During the research years, the trophic state of the Ket corresponded to the eutrophic category, eutrophic class, water quality class 3 «satisfactory purity», category 3b «slightly polluted».

Discussion

In summer, in the mouth of the Ket there're favourable conditions for phytoplankton development: low flow velocity, sufficient depth and temperature of water, low mineralization, neutral or slightly alkaline environment. In general, this is typical for most of the recently studied tributaries of the middle course of the Ob River that enrich it with diverse and abundant phytoplankton (Barsukova et al. 2022; Bazhenova and Barsukova 2022).

There are several large tributaries that fall into the middle course of the Ob. These include, first of all, the Irtysh, comparable in its water content with the Ob, as well as the Tom, Ket, Chulym, Chaya, Parabel, Vasyugan, etc. The phytoplankton of the upper and middle Irtysh has been most studied, which made it possible to assess the ecological state of the river and predict its changes (Bazhenova 2005; Bazhenova and Gulchenko 2017). Phytoplankton and the ecological state of the Tom have been studied deeply enough (Ioganzen et al. 1951; Yakubova 1951; Novikova 1991; Naumenko 1993; Golubykh 1996, 2007; Mitrofanova 2007, 2008). Algae of the most of other tributaries have not been studied. Only in 2022, the first scientific information about the phytoplankton of the Vasyugan and the Ket appeared (Barsukova et al. 2022; Bazhenova and Barsukova 2022).

The taxonomic structure of the phytoplankton of the Ket River generally corresponds to the modern structure of the phytoplankton of the Ob River (Barsukova et al. 2021), but differs from its structure established at the end of the 20th century. So, at present, no cryptophyte algae have been found in the phytoplankton of the Ob (and Ket), but at the end of the 20th century, cryptophytes were present in the Ob, although they did not differ in species richness and abundance (Naumenko 1995, 1996).

Is also has great similarity with another tributary of the Ob – Vasyugan (Barsukova et al. 2022; Bazhenova and Barsukova 2022), as well as with the right-bank tributaries of the middle Irtysh, which flow from swamps through the forest zone – rivers Tara and Uy (Barsukova and Bazhenova 2012). In terms of the taxonomic structure of phytoplankton of these rivers, as well as in the Ket, green algae predominate, and euglenids make up a significant proportion.

It should be noted that the intensive vegetation of small-celled green algae species, as established in the Ket, is a characteristic feature of phytoplankton that occurs during anthropogenic eutrophication of water bodies and is observed in the main tributary of the Ob – Irtysh (Bazhenova 2005), in many rivers and lakes of the basin of its middle reaches (Bazhenova et al. 2019), Ob (Barsukova et al. 2021), Yenisei (Kozhevnikova 2001). It is also known that small-celled algae are highly productive and able to actively consume low-molecular dissolved organic matter, contributing to self-purification of water bodies (Sadchikov and Makarov 2000)

Euglenids are another notable phytoplankton component in West Siberia water bodies, including basins of the Ob and Irtysh rivers (Safonova 1987). *Trachelomonas* genus is the most widespread among them (Safonova 1972; Bazhenova et al. 2019). The species richness of euglenids in the Ket is primarily due to the swamp origin of the river. However, it should be taken into account that widespread distribution of euglenids in the water bodies of West Siberia is also due to increased anthropogenic eutrophication of rivers and lakes in the region observed since the end of the twentieth century (Safonova 1987; Bazhenova 2005; Bazhenova et al. 2019).

Most cyanoprokaryotes found in the Ket plankton are widely distributed in various water bodies of Western Siberia. Small-celled non-heterocyst species, are the most common in their composition. These species ofter cause «flowering» of water bodies in various geographical zones, and mass development of these species occurs with an increase in the trophic status of waters (Korneva 2015; Bazhenova and Mikhailov 2021).

Golden algae found in the Ket are often seen in other rivers of West Siberia – the Ob, Irtysh and their tributaries (Naumenko 1992; Barsukova and Bazhenova 2012; Bazhenova et al. 2019). In addition, in the Ket, same as in the Vasyugan, Kephyrion impletum Nyg. and *Pseudokephyrion pseudospirale* Bourr. were found. Initially these species had been found in the middle course of the Ob (Bazhenova and Barsukova 2021; Barsukova et al. 2022).

Ecological groups composition of the found species reflects conditions prevailing in the river and its geographical location. Predominance of cosmopolitans is a feature of water bodies located in temperate climate (Barinova et al. 2006). High proportion of planktonic-benthic and epiphytic species (51.61%) is typical for so-called potamoplankton. The majority of saprobity indicator species (53.55%) belong to inhabitants of polluted and dirty waters. It shows a high content of organic substances in the Ket and may be associated not only with its swamp origin, but also with increased anthropogenic impact on the river. At the same time, a significant proportion (33.55%) of widely tolerant species indicates a high potential for self-cleaning ability of the river, which ensures stability of its ecosystem (Odum 1986).

Alpha diversity parameters of the Ket phytoplankton are rather high, and in summer 2019 they were close to that of the Ob River (Barsukova et al. 2021). Margalef index showes high diversity of the phytoplanktocenosis, and the Shannon index indicatees a structure of phytoplanktocenosis that is close to average complexity. The value of the Simpson index, which is a very sensitive indicator of the dominance of a small number of species (Rosenberg 2007), was twice as high in 2021 as in 2019, which reflects the changes noted above in the dominant complex of phytoplankton species of the Ket. In general, the alpha diversity indicators corresponds to the prosperous state of the phytoplanktocenosis of the Kety.

In 2019, the trophic state and water quality of the Ket coincided with the indicators of the entire course of the Ob and another major tributary of the Ob – Vasyugan (Barsukova et al. 2021 2022).

Conclusions

The phytoplankton of the Ket River is rich and diverse, which is due to the flat nature of the river, the large area of the drainage basin, and other hydrological and morphometric factors that favor its development. The marsh origin of the river plays an important role in the formation of species richness and structure of phytoplankton.

The state of Ket's phytoplanktocenosis, assessed by alpha-diversity parameters, is quite favorable, but some structural indicators of phytoplankton, identified during the study, indicate the development of negative phenomena. Examples are the predominance of small-celled green algae in phytoplankton, intensive vegetation of non-heterocyst cyanoprokaryotes, significant fluctuations in the number of phytoplankton over the years, and a high proportion of β-mesosaprobionts among the indicator species of water saprobity. Taken together, these phenomena characterize the beginning of eutrophication of the river ecosystem, and the flat nature of the river and its high trophic status can contribute to this process. To assess the direction of changes in the ecosystem of the Ket River, it is necessary to conduct further studies of its phytoplankton.

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Supplementary material 1

Species composition of algae in the Ket River, 2019–2021

Authors: Olga P. Bazhenova, Natalya N. Barsukova Data type: Table

Explanation note: The table contains information on the ecological and geographical characteristics of the algae species of the Ket River, obtained as a result of the research in 2019-2021.

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