Short Communication:
Assessing phytoplankton species structure in trophically different water bodies of South Ural, Russia

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Tel./Fax. +7-351-2679517, ♥email: kostriukovaam@susu.ru
[2]Institute of Linguistics and International Communications, South Ural State University. 76 Lenin Prospect, 454080 Chelyabinsk, Russia
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Abstract. *Kostryukova A, Mashkova I, Belov S, Shchelkanova E, Trofimenko V. 2021. Short Communication: Assessing phytoplankton species structure in trophically different water bodies of South Ural, Russia. Biodiversitas 22: 3530-3538.* The study aims to analyze the species structure of the phytoplankton communities of four water bodies in South Ural (Lakes-Turgoyak, Uvildy, Ilmenskoe and Shershnevskoe reservoir). These water bodies are characterized by different trophic states and levels of anthropogenic impact. Lake Turgoyak is oligotrophic; Lake Uvildy is oligomesotrophic. Both water bodies are protected areas and natural monuments. But tourism and recreation are not prohibited on their territories. The mesoeutrophic Lake Ilmenskoe is partially located within the Ilmen State Reserve, and it experiences less anthropogenic impact. The eutrophic Shershnevskoe reservoir is located within the boundaries of the city of Chelyabinsk. It is used as a source of drinking water. Cyanobacteria was the dominant division in the eutrophic Shershnevskoe reservoir. Bacillariophyta dominated in the plankton communities in oligotrophic Lake Turgoyak and oligomesotrophic Lake Uvildy. Green and blue-green algae biodiversity increased in the oligomesotrophic Lake Uvildy. For the mesoeutrophic Lake Ilmenskoe, diatom algae are dominant, but a higher proportion of Chlorophyta (especially Cyanobacteria) was revealed. Species similarity among phytoplankton communities in the given lakes was studied through cluster analysis based on the Sorensen-Czekanowski coefficient. The higher level of similarity between plankton species compositions could be explained by their locality rather than their trophic status.

Keywords: Biodiversity, species structure, Lake Turgoyak, Lake Uvildy, Lake Ilmenskoe, phytoplankton, Shershevskoe Reservoir

INTRODUCTION

All living communities naturally change their structure, and algae is not an exception (Ansari and Gill 2014; Paulino et al. 2018; Bazarova et al. 2019). This change is a rather long process, and there is no singular opinion on the reasons for transformations in species structure. However, human activity has a significant impact on the succession of phytoplankton communities (Setyono and Himawan 2018; Mashkova et al. 2020a; Namsaraev et al. 2020). Phytoplankton responds quickly to changes in its aquatic environment, which allows it to be used as a bioindicator. Microalgae are also very sensitive and respond quickly to decreased water quality caused by human activity (Setyono and Himawan 2018). Eutrophication, which influences aquatic biodiversity, affects many water bodies around the world and is considered a global issue (Ansari and Gill 2013; Ismest'eva et al. 2015; Viaroli et al. 2015; Gao et al. 2020; Pratiwi et al. 2020). Eutrophication leads to higher trophic states. Increased biogenic element intake from a catchment area due to human activity leads to the transformation of phytoplankton community structure, changes in season dynamics of the biomass and the increased significance of some species (Snit'ko 2009; Suda et al. 2016; Pratiwi et al. 2018; Song et al. 2019; Wang et al. 2020; Yang et al. 2020). Pearsall (1932) first defined the main transformations in lake algae composition after enrichment by biogenic elements. He studied nine lakes in England with well-defined plankton types. Among them were rocky lakes with primarily green plankton, silted lakes with primarily blue-green algae and lakes with primarily diatoms. Pearsall revealed the following pattern in his work: the communities change from a predominance of yellow-green algae (Chrysophyta), desmid algae (Chlorophyta Desmidiales) and diatom (Baccilariophyta) with low biomass to a predominance of blue-green (Cyanobacteria) with high biomass (Snit'ko 2009). Rakocevic-Nedovic and Hollert (2005) registered the qualitative dominance of Chlorophyta and Bacillariophyta in the mesotrophic Lake Scadar (Montenegro, Balkan) throughout the year of study. Diatoms dominated in spring with the population peak in May (Rakocevic-Nedovic and Hollert 2005). In summer they remained quite numerous. However, in June, green algae became dominant. Blue-green algae dominated the community late in summer with the population peak reached in August. Diatoms were dominant again in winter (Rakocevic-Nedovic and Hollert 2005). Ayoade et al. (2019) marked the abundance of Cyanophyta and Chlorophyta in eutrophic water bodies from April till October.

The Chelyabinsk region (part of the South Ural region) is an industrial and agricultural zone with 88.5 thousand m^2 of land. It is located on the border of Europe and Asia in the southern part of the Urals and on the adjusting West Siberian plain (Figure 1). The major industries are iron and steel, mechanical engineering, non-ferrous industry (copper, zinc, and nickel production), chemical production and others. These industries have a negative impact on the environment (Ministry of Ecology of the Chelyabinsk Region 2019). The Chelyabinsk region has more than 3000 water bodies (Levit 2005). Of these numerous water bodies, only 100 have a surface area of more than 5 km^2. The region's water bodies are predominantly smaller than 1 km^2 in surface area. Most of the large lakes are widely used for recreation (Besedin et al. 2000; Veisberg et al. 2015; Zakharov 2018).

The natural water bodies of Chelyabinsk region are closely studied. The human impact on water bodies and their shores and, on flora and fauna (phytoplankton and zooplankton communities, macrophytes, mollusks and fish) are assessed. The changing chemical indices of water receive a great deal of attention. The studies are comprehensive and give a full review of water bodies. The trophic status of South Ural water bodies has been widely studied using different methods. Mashkova et al. (2021) researched the trophic status of the Chelyabinsk region water bodies by the zooplankton community. The ecological state of aquatic ecosystems was repeatedly studied using qualitative and quantitative methods to assess phytoplankton (Kostryukova et al. 2019, 2020). But there is little significant research on phytoplankton communities in Chelyabinsk region water bodies. The most important works are by Snit'ko and Sergeeva (2003), Yarushina et al. (2004). They provided the general characteristics of plankton in the region and studied the specific features of the species composition and taxonomic structure of algae communities. Snit'ko (2009) provided information on phytoplankton in various South Ural water bodies subject to human impact.

The composition and structure of phytoplankton in water bodies show the status of the water system. With increased human impact on water bodies, the structure, population size and biomass of phytoplankton change. The study aims to study possible relations between the changes of species structure of phytoplankton community and the trophic status of water bodies.

MATERIALS AND METHODS

Study area

Four water bodies in the South Ural region with different trophic status were selected for study: Turgoyak, an oligotrophic lake; Uvildy, an oligomesotrophic lake; Ilmenskoe, a mesoeutrophic lake; and the Shershnevskoe reservoir, a eutrophic water body (Figure 1).

Characteristics of water bodies

The morphology of the water bodies is given in Table 1. Turgoyak and Uvildy are large and deep lakes with a surface area of over 10 km^2 and a depth of more than 20 km. Ilmenskoe is medium-sized (1-10 km^2) but shallow. The water surface area of the Shershnevskoe reservoir allows for its classification as a large lake, but it is shallow (Snit'ko 2009). According to the chemical composition, the lakes belong to the hydrocarbonate class of the calcium group (Snit'ko 2009). All the chosen lakes and the Shershnevskoe reservoir are freshwater bodies. The salinity of Turgoyak and Ilmenskoe does not exceed 300 mg.L^{-1}, Uvildy is measured at 370-390 mg.L^{-1}, and the Shershnevskoe reservoir – 400-500 mg.L^{-1} (Snit'ko 2009).

Anthropogenic impact on water bodies

Lake Turgoyak is near the city of Miass (population >150,000). Automobile building is the predominant industry. Lake Turgoyak was recognized as a natural monument in 1969. Natural monuments are created to preserve small areas of valuable natural objects. Environmental, scientific, educational and recreational activities are allowed on their territory. They are actively used for sightseeing, tourism and recreation (Federal Law 1995). Lake Turgoyak experiences an adverse human impact from recreation, with 50,000-100,000 tourists visiting each year (Zakharov 2018). Water from Lake Turgoyak was used for economic needs from 1952 untill the early 1990-s. The water intake exceeded the average water balance of the lake for many years, i.e. more than 5-6 mlnm^3×year^{-1} (Zakharov 2018).

Figure 1. Map of Chelyabinsk region, Russia with locations of the studied lakes: 1. Lake Turgoyak, 2. Lake Uvildy, 3. Lake Ilmenskoe, 4. Shershnevskoe reservoir

Table 1. Morphological parameters of water bodies.

Water bodies	Elevation (m asl.)	Water surface area (km²)	Water volume (mlnm³)	Depth (m)	
				Maximal	Average
Turgoyak (oligotrophic lake)	318.9	26.40	507.0	34.5	19.2
Uvildy (oligomesotrophic lake)	272.0	68.10	1014.0	38.0	13.0
Ilmenskoe (mesoeutrophic lake)	331.4	4.56	14.6	6.1	3.0
Shershnevskoe (eutrophic reservoir)	222.0	39.00	160.0	14.0	4.0

Lake Uvildy is the largest lake in the South Ural region. There are many villages, resorts and recreation centres on its shores. The lake is exposed to an adverse human impact from recreation. It has been listed as a natural monument since 1969. Around a quarter of the lake water was pumped into the Argazinskoe reservoir to supply the city of Chelyabinsk with drinking water. The water level decreased almost by 4 m. Trees and shrubs grew on the drained land and were subsequently drowned in 2006 when the water level was restored. This resulted in eutrophication.

Lake Ilmenskoe is partially located in the Ilmen State Reserve and on the eastern shore of the city of Miass. A road and a railway run along the northern and eastern shores. There is a recreational area on the west shore. The southern shore is swampy.

The Shershnevskoe reservoir is located in Chelyabinsk and serves as a water source. It was filled with water from 1965-1969. There are numerous resorts, cottages and residential areas on its watershed. As a result, it experiences an adverse human impact (Kostryukova et al. 2019; Kostryukova et al. 2020; Mashkova et al. 2020b).

Identification of phytoplankton species

The study is based on our own collected data, as well as on the data of other researchers studying phytoplankton of these water bodies. The species composition of phytoplankton communities was identified: (i) for Turgoyak-according to research data from 1998-2006 (Snit'ko 2009; Snit'ko and Snit'ko 2012; Yarushina et al. 2004); (ii) for Uvildy-according to research data from (2005-2006) (Snit'ko and Sergeeva 2003; Yarushina et al. 2004) and our research (2014-2016); (iii) for Ilmenskoe-according to research data from 1998-2003 (Snit'ko and Sergeeva 2003; Snit'ko 2009; Yarushina et al. 2004) and our research in 2011-2016; (iv) for Shershnevskoe reservoir-according to research data from (2005-2006) (Snit'ko and Sergeeva 2003; Yarushina et al. 2004) our

research (2014-2016). At each site, samples were collected and filtered through a plankton net (mesh size: 100 μm). The retained organisms were transferred into glass containers. The collected material was preserved in 5% formalin.

Non-diatom algae were analyzed using a magnification of 600× (Altami BIO 2T microscope, Altami Ltd., St. Petersburg, Russia). Permanent diatom slides were prepared after oxidizing the organic material (by nitric acid and sulfuric acid), and at least 300 valves were counted for each sample using an Altami BIO 2T microscope at 1000× under oil immersion.

Species were identified using handbooks (Al-Kandari et al. 2009; Yarushina et al. 2004). Taxonomic characteristics were specified following algae determinants (Guiry and Guiry 2020; WoRMS 2019).

The dominant species included those species whose frequency of occurrence on the Starmach scale (Starmach 1963) was more than 30 organisms in the specimen. The frequency of occurrence of organisms of a certain species on the Starmach scale is estimated as follows (Table 2).

Data analysis

We chose the cluster analysis method to study the species similarity of the phytoplankton communities of the studied lakes. The data were analyzed using the Sorensen-Chekanowski coefficient of species similarity:

$$Is=2c/(a+b)$$

Where: a is the number of species in one community; b is the number of species in another community; c is the number of species common to the two communities. The limits of this coefficient are from 0 to 100%, where 100% is a complete similarity of communities (the absolute coincidence of lists), and 0% means that they have no common species.

Table 2. The frequency of occurrence of organisms of a certain species on the starmach scale

The frequency of occurrence of organisms	Points	Characteristics
The species is not present in every specimen	+	Sporadically
1-6 organisms in the specimen	1	Very rarely
7-16 organisms in the specimen	2	Rarely
17-30 organisms in the specimen	3	Often
31-50 organisms in the specimen	4	Very often
31-50 organisms in the specimen	5	Absolute predominance, absolute predominance

RESULTS AND DISCUSSION

Results

The results are presented in a dendrogram. Dendrograms are used to compare the taxonomic composition of algae of different water bodies or different areas of the same water body (Barinova and Smith 2019; Komulaynen 2018; Malakhov et al. 2017). The dendrogram was calculated using a special comparative floristic program GRAPHS (Nowakowski 2004).

The largest number of microalgae species in Lake Turgoyak are from four main divisions: Bacillariophyta, Charophyta, Chlorophyta, and Cyanobacteria. When comparing the taxonomic composition (Figure 2), we discovered that the microalgae of the Bacillariophyta division played a key role in the formation of phytoplankton communities of the oligotrophic Lake Turgoyak (about half of all microalgae species of this lake, 44% of the total number of species). The number of microalgae species of the Charophyta division in this lake is two times fewer (21% of the total number of species). The family Desmidiales (specifically, the genera *Cosmarium* (10 sp.) and *Staurastrum* (9 sp.)) determine the higher species diversity of phytoplankton in this group. For the other water bodies, the proportion of species abundance of *Cosmarium* genus and *Staurastrum* genus is significantly lower. Desmids are used as indicators of water quality as they are sensitive to any changes in water bodies (Coesel 2001; Aquino et al. 2018). They are typical representatives of the flora of oligotrophic and mesotrophic aquatic systems (Aquino et al. 2018). There are even fewer green microalgae (14% of the total species number) and blue-green algae (8% of the total species number) in Lake Turgoyak. The other divisions account only for 13% of the total species number.

Discussion

According to Snit'ko (2009) and Trifonova (1990) the predominance of the Bacillariophyta division is a characteristic feature of deep mountain lakes, including Turgoyak. A similar pattern of species distribution by divisions is observed, for example, in mountain water bodies of the Ergaki Ridge (Krasnoyarsk Territory) (Makeeva and Denisova 2017). According to these authors, the highest species diversity is characteristic of Bacillariophyta (44%) and Charophyta (21.2%). The proportion of Chlorophyta and Cyanobacteria is 14% and 13.3%, respectively. Bogdanov et al. (2004), Chekryzheva (2017), Trifonova (1990) and Sharov (2020) also note the highest species diversity of diatoms in the majority of oligotrophic and mesotrophic water bodies of the North-West region of the European part of Russia, mountain lakes of the Polar Ural region and water bodies of the temperate climate zone.

The highest phytoplankton biodiversity in Lake Turgoyak is characteristic for the following families: Desmidiaceae (24 sp.), Surirellaceae (9 sp.), Naviculaceae (8 sp.), Rhopalodiaceae (7 sp.), Stephanodiscaceae (7 sp.), Fragilariaceae (6 sp.), Cymbellaceae (6 sp.) and Eunotiaceae (6 sp.) (Table 4). They make up 40.1% of the total species composition of this lake. Analyzing the Genus taxonomic unit, we identified the following genera rich in species: *Cosmarium* (10 sp.), *Staurastrum* (9 sp.), *Surirella* (6 sp.), and *Eunotia* (6 sp.).

The distribution of microalgae species in the oligomesotrophic Lake Uvildy is different. Bacillariophyta, Chlorophyta and Cyanobacteria had the greatest number of species. They account for 30%, 24% and 24% of the total number of species respectively (Figure 2). The blue-green microalgae of Lake Uvildy are rich in species, which is not characteristic of this type of mountain water body. Unlike Lake Turgoyak, the proportion of microalgae of the Charophyta division in the species diversity of the community is significantly lower (7% of the total number of species). The composition of the leading phytoplankton families of Lake Uvildy differs from Lake Turgoyak. The leading algae families of Lake Uvildy are shown in Table 3. The total number of species registered is: Euglenaceae (7 sp.), Desmidiaceae (6 sp.), Aphanizomenonaceae (6 sp.), Oscillatoriaceae (6 sp.), and Hydrodictyaceae (6 sp.). These families include 25.2% of microalgae species of the total species composition of microalgae in Lake Uvildy. Unlike lake Turgoyak, for Lake Uvildy the genera rich in species include *Epithemia* (4 sp.) and *Euglena* (4 sp.).

For the mesoeutrophic Lake Ilmenskoe, diatom algae are dominant accounting for 40%. The proportion of blue-green and green algae are 22% and 17% respectively. The increased proportion of blue-green algae is associated with higher trophic activity and water pollution. The leading algae families of Lake Ilmenskoe (Table 4) include Microcystaceae (7 sp.), Dinobryaceae (7 sp.), Desmidiaceae (7 sp.), Gomphonemataceae (7 sp.), Naviculaceae (7 sp.), Euglenaceae (6 sp.), and Cymbellaceae (6 sp.). These families include 29.2% of the total microalgae species composition of Lake Ilmenskoe. The Desmidiaceae family has the highest species diversity in all three lakes (Turgoyak, Uvildy and Ilmenskoe). The genus Dinobryon (6 sp.) is the richest in species.
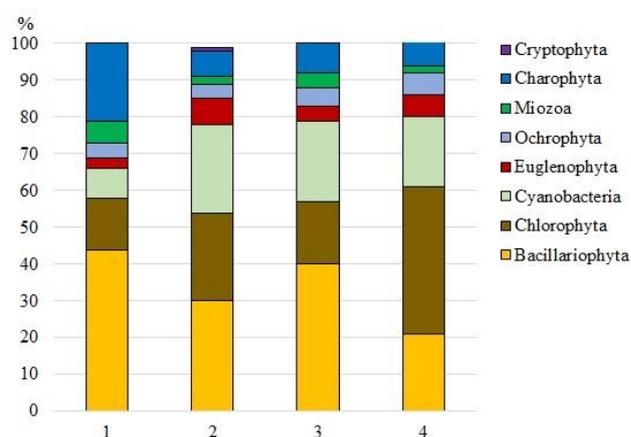

Figure 2. Abundance of microalgae species (% of total species number) in the studied water-bodies: 1. Lake Turgoyak, 2. Lake Uvildy, 3. Lake Ilmenskoe, 4. Shershnevskoe reservoir.

Table 3. Taxonomic composition of phytoplankton communities in the studied water bodies of South Ural, Russia

Algae taxa		Sites			
Divisions	Class	Lake Turgoyak	Lake Uvildy	Lake Ilmenskoe	Shershnevskoe Reservoir
Bacillariophyta	Mediophyceae	8	2	4	6
	Coscinodiscophyceae	2	2	4	4
	Bacillariophyceae	62	33	55	24
	Bacillariophyta classis incertae sedis	-	-	1	-
	Total	72	37	64	34
Chlorophyta	Chlorophyceae	18	23	22	50
	Trebouxiophyceae	4	6	3	13
	Ulvophyceae	-	1	2	1
	Total	22	30	27	64
Cyanobacteria	Cyanophyceae	13	29	35	31
Euglenozoa	Euglenophyceae	5	9	7	9
Ochrophyta	Chrysophyceae	4	4	7	5
	Xanthophyceae	2	1	1	2
	Synurophyceae	-	-	-	2
	Total	6	5	8	9
Miozoa	Dinophyceae	10	3	6	3
Charophyta	Zygnematophyceae	31	9	13	10
	Klebsormidiophyceae	3	-	-	2
	Total	34	9	13	12
Cryptophyta	Cryptophyceae	-	1	1	-
Total		162	123	161	162

Table 4. Phytoplankton species number in the leading families and genera in the studied water bodies of South Ural, Russia

Family/genus	Lake Turgoyak	Lake Uvildy	Lake Ilmenskoe	Shershnevskoe reservoir
Bacillariophyta				
Surirellaceae/Surirella	9/6	3/2	2/2	1/1
Naviculaceae/Navicula	8/5	2/1	7/4	1/1
Stephanodiscaceae	7	1	2	4
Rhopalodiaceae/Epithemia	7/7	4/4	3/3	2/2
Fragilariaceae/Fragilaria	6/4	4/3	5/3	2/2
Cymbellaceae/Cymbella	6/5	3/3	6/5	1/1
Eunotiaceae/Eunotia	6/6	0/0	1/1	0/0
Gomphonemataceae/Gomphonema	2/0	2/2	7/4	3/1
Charophyta				
Desmidiaceae/Staurastrum/Cosmarium	24/9/10	6/2/2	7/3/3	5/4/1
Chlorophyta				
Scenedesmaceae/Desmodesmus/Scenedesmus/Tetradesmus	2/0/0/0	3/0/1/2	3/1/0/0	16/3/3/4
Selenastraceae/Monoraphidium	0/0	4/2	1/0	9/4
Hydrodictyaceae/Tetraedron	3/0	6/1	4/0	7/3
Cyanobacteria				
Oscillatoriaceae/Oscillatoria	2/1	6/4	3/2	0/0
Aphanizomenonaceae/Dolichospermum	4/4	6/3	5/5	9/7
Microcystaceae/Microcystis	2/2	2/2	7/5	6/6

The eutrophic Shershnevskoe reservoir is marked by the richest species diversity of green algae (40%) with the proportions of diatom and blue-green algae, 21% and 19% respectively (Figure 2). The water bodies with higher trophic status are characterized by a much scantier composition of diatom plankton and the predominance of green algae in the community (Snit'ko 2009). The obtained results correspond to the previous data (Eremkina 2010), according to which the higher the trophic status of the

water body, the richer the biodiversity of green and euglenic algae and the lower the biodiversity of diatoms and dinophytes. Higher species diversity of green algae compared to diatoms was also observed in water bodies of the Middle and Lower Volga, the eutrophic water bodies of the Volga region (Samara region) and Karelia (Chekryzheva 2017; Malysheva et al. 2018; Sharov 2020). The shallow depth of the Shershnevskoe reservoir and the increased biogenic load increased the temperature of the

water mass and create favorable conditions for the development of green algae.

The leading algae families of the Shershnevskoe reservoir (Table 4) include Scenedesmaceae (16 sp.), Selenastraceae (9 sp.), Aphanizomenonaceae (9 sp.), Hydrodictyaceae (7 sp.) and Phacaceae (6 sp.). These families make up 27.8% of the species of the total species composition in the Shershnevskoe reservoir. Dolichospermum genus (7 sp.) and Microcystis (6 sp.) are represented more richly in the Shershnevskoe reservoir than in other studied water bodies.

Table 4 shows that 7 families with the highest species abundance (6-9 sp.) were found in the algae of the Bacillariophyta division of the oligotrophic Lake Turgoyak. Moreover, in each family, we identified a genus that determines the species abundance. 4-7 species were registered in each of these leading genera. The exception was the Stephanodiscaceae family which united only one- and two-species genera. This pattern was not observed in other water bodies. The Naviculaceae and Cymbellaceae families preserve a large number of species in Lakes Uvildy and Ilmenskoe. However, in the eutrophic Shershnevskoe reservoir, the species diversity of diatomics is reducing significantly.

The large proportion of the algae of the Charophyta division, particularly of the Desmidiaceae family, is another feature of the phytoplankton species structure of Lake Turgoyak that distinguishes it from other water bodies. The presence of 24 species of this family indicates the oligotrophic status of the lake.

The high species abundance of the Chlorophyta division was only observed in the eutrophic Shershnevskoe reservoir (7-16 sp.). Apparently, the optimal conditions for the development of species of this division have been created in the eutrophic Shershnevskoe reservoir, which allows them to compete with other algae.

There is no clear relationship between species abundance and the trophic status of the water body for the Cyanobacteria division. The families with the least number of species are recorded in the algae community of the oligotrophic Lake Turgoyak.

Thus, four main departments of phytoplankton communities of the studied water bodies could be distinguished, differences in the species diversity of which indirectly reflect changes in the trophic status. Diatoms are the dominant department in terms of species diversity in all three lakes that have a lower level of eutrophication compared to the reservoir. They are often used as indicators of the ecological state of water bodies. On the one hand, developing eutrophication results in an increasing number of planktonic diatoms (Weckström et al. 2007). Weckström et al. 2007 attribute this to a growing water turbidity (due to an increase in the number of suspended particles and the total productivity of plankton), which in turn leads to the creation of more favorable conditions for the development of individual groups of diatoms. On the other hand, eutrophication leads to a decreasing species diversity of algae in this department. The high species richness of microalgae of the Charophyta department can be used as an

indicator of the good ecological condition of water bodies. More than 30 species of algae of this department were present in the water of the oligotrophic lake. The species diversity of blue-green algae increases in mesotrophic and eutrophic water bodies. According to Hall and Smol (1999), an increase in the N:P ratio during eutrophication leads to the replacement of small diatoms with larger cyanobacteria, which are more competitive in terms of nitrogen use. For those cyanobacteria that do not fix nitrogen or are less effective nitrogen competitors, their higher diversity in mesotrophic and eutrophic water bodies may be determined by the fact that they are more competitive with respect to light in water bodies with increased turbidity (Downing et al. 2001). A significant predominance of green algae species in the eutrophic reservoir may indicate a deterioration of its ecological status towards hypertrophy (Jensen et al. 1994). Green algae dominate in hypertrophic reservoirs, because in conditions of an excess of nutrients they have higher growth rates and are stronger competitors compared to relatively slow-growing cyanobacteria (Jensen et al. 1994; Ma et al. 2014).

Also, we compared the species composition of algae communities using the comparative floral program GRAPHS (Nowakowski 2004). We designed a dendrogram based on the Sorensen-Chekanowski coefficient (Figure 3). The species composition revealed more similarities between the oligotrophic Lake Turgoyak and the mesoeutrophic Lake Ilmenskoe than with the oligomesotrophic Lake Uvildy. The higher similarity between species compositions of Turgoyak and Ilmenskoe than Turgoyak and Uvildy could be explained by their location not their trophic status. Turgoyak and Ilmenskoe are closer to each other. The taxonomic structure of the algae of the Shershnevskoe reservoir coincides with the structures of other water bodies by just 26%.
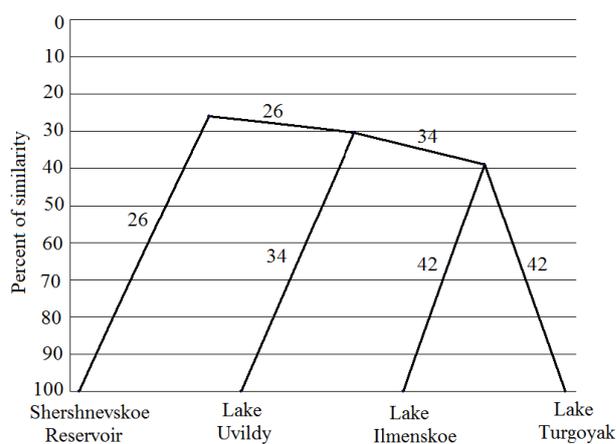

Figure 3. Dendrogram of the similarity of phytoplankton composition in the studied water bodies (Sorensen-Czekanowski coefficient)

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Table 5. Dominant species of phytoplankton composition in the studied water bodies in South Ural, Russia

Species	Lake Turgoyak	Lake Uvildy	Lake Ilmenskoe	Shershnevskoe reservoir
Bacillariophyta				
Asterionella formosa Hassall 1830	+	+		+
Aulacoseira granulata (Ehrenberg) Simonsen 1545		+		
Fragilaria crotonensis Kitton 1865	+	+	+	
Fragilaria acus (Kützing) Lange-Bertalot 2000		+		
Epithemia gibba (Ehrenberg) Kützing 1844		+		
Ulnaria ulna (Nitzsch) Compère 2001			+	
Cyanobacteria				
Anabaena aequalis O.Borge 1906		+		
Aphanizomenon flos-aquae (Linnaeus) Ralfs ex Bornet & Flahault 1888		+		+
Dolichospermum flosaquae (Brébisson ex Bornet & Flahault) P.Wacklin, L.Hoffmann & J.Komárek 2005	+	+	+	+
Dolichospermum lemmermannii (Ricter) P.Wacklin, L.Hoffmann & J.Komárek 2005		+		+
Dolichospermum macrosporum (Klebhan) Wacklin, L.Hoffmann & Komárek 2005				+
Dolichospermum planctonicum (Brunnthaler) Wacklin, L.Hoffmann & Komárek 2005				+
Dolichospermum spiroides (Klebhan) Wacklin, L.Hoffmann & Komárek 2005				+
Gloeotrichia echinulata P.G.Richter 1854		+	+	
Microcystis aeruginosa (Kützing) Kützing 1846			+	+
Microcystis flosaquae (Wittrock) Kirchner 1858			+	
Microcystis pulverea (H.C.Wood) Forti 1504	+			
Microcystis wesenbergii (Komárek) Komárek ex Komárek 2006			+	
Snowella lacustris (Chodat) Komárek & Hindák 1588				+
Planktothrix agardhii (Gomont) Anagnostidis & Komárek 1588				+
Johanseninema constrictum (Szafer) Hasler, Dvorák & Poulícková 2014				+
Anabaena contorta Bachmann 1521				+
Chlorophyta				
Raphidocelis mucosa (Korshikov) Komarek 1545		+		
Scenedesmus quadricauda (Turpin) Brébisson 1833		+		
Pseudopediastrum boryanum (Turpin) E.Hegewald 2003		+		
Pediastrum duplex Meyen 1825	+	+		
Ochrophyta				
Dinobryon divergens O.E.Imhof 1884	+	+	+	
*Dinobryon sociale var. americanum (*Brunnthaler) Bachmann 1911		+		
Uroglenopsis americana (G.N.Calkins) Lemmermann 1899		+		
Charophyta				
Staurastrum gracile Ralfs ex Ralfs 1848	+		+	
Desmidium swartzii C.Agardh ex Ralfs 1848	+			
Euglenozoa				
Lepocinclis acus (O.F.Müller) Marin & Melkonian, 2003	+			
Miozoa				
Apocalathium aciculiferum (Lemmermann) Craveiro, Daugbjerg, Moestrup & Calado 2016	+			
Ceratium hirundinella (O.F.Müller) Dujardin 1841		+	+	

Note: 1-Lake Turgoyak, 2-Lake Uvildy, 3-Lake Ilmenskoe, 4-Shershnevskoe Reservoir

A   **B**   **C**   **D**

Figure 4. Some dominant phytoplankton species of phytoplankton composition in the studied water bodies (Lake Turgoyak, Lake Uvildy, Lake Ilmenskoe, Shershnevskoe Reservoir) (x200): A. *Asterionella formosa* Hassall 1830, B. *Fragilaria crotonensis* Kitton 1865, C. *Microcystis aeruginosa* (Kützing) Kützing 1846, D. *Gloeotrichia echinulata* P.G. Richter 1854

The dominant algae species (frequency of more than 30 organisms in the specimen) of the studied lakes are presented in Table 5 and Figure 4. Among the dominant phytoplankton complexes of water bodies with an increasing trophic status, blue-green algae dominate (Lake Ilmenskoe and Shershnevskoe reservoir). Plankton of Cyanobacteria division are the basis for the dominant complex for the eutrophic water body. The dominant complex of the oligotrophic deep Lake Turgoyak is represented by all the microalgae divisions equally.

In summation, there is a relationship between the changing phytoplankton structure and the water body trophic status. Some features could be used to forecast changes in the trophic status. In oligotrophic lakes, algae of

the Bacillariophyta division play a leading role in the formation of a plankton community. There is also a high species abundance of algae of the Charophyta division, namely, the Desmidiaceae family. Desmids are characterized by high sensitivity to changing environmental conditions. In mesoeutrophic and eutrophic water bodies, the number of Desmids species is significantly lower. An increase in the proportion of Chlorophyta, especially Cyanobacteria, indicates a deterioration in the trophic status of a water body. Algae of the Chlorophyta division predominate in species diversity in eutrophic water bodies. Blue-green algae form the basis of the dominant plankton complex in water bodies with high trophic status.

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