ALGAL FLORA OF THE PONDS, LOCATED WITHIN THE CITY OF VYKSA (NIZHNY NOVGOROD REGION OF THE RUSSIAN FEDERATION)

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Abstract:
The article presents the results of studies of planktonic algae of ponds, located within the city of Vyksa, for 2017-2018. During the period of observation, 110 taxa were found in the phytoplankton of the studied water bodies. Phytoplankton was formed by diatoms, green, blue-green and euglena algae. The highest values of the abundance and biomass were typical for the Vil'skiy pond. The lowest values of the abundance and biomass were observed in the Verkhnevyksunsky pond. The quality of water in majority of the studied reservoirs was estimated as mesosaprobic. According to the indicators of water trophicity, most of the studied objects are mesotrophic. The highest values of the indices of saprobity and trophicity were defined in the Vil'skiy pond, the water quality of which corresponded to the eutrophic and hypereutrophic types.

Keywords: *algocenosis, algae, phytoplankton, Vyksa city, Zheleznitsa River, pond.*

INTRODUCTION

The city of Vyksa is an administrative-territorial (the city of regional significance) and a municipal formation with the status of an urban district in the Nizhny Novgorod region of the Russian Federation. Currently, the city of Vyksa is one of the largest industrial centers of the region. Its production is represented by 15 large enterprises.

For the development of ferrous metallurgy, several large artificial factory ponds were created in this area. Four of five largest ponds of the Nizhny Novgorod region are located within the urban district of Vyksa. These reservoirs are the part of the previously existing Vyksa hydropower system. In the 18th century it operated the mechanisms of seven metallurgical plants, and two flour mills, using the water of the Zheleznitsa River nine times. [5]. Nowadays, the cascade of ponds is a place for recreation and fishing. These reservoirs are the object of cultural heritage.

The results of investigations of planktonic algae of ponds, located within the city of Vyksa, are presented in the article. To date, there are very few published works on the study of hydrobiont communities of water bodies in the Vyksa urban district. There is no information about the algal flora of these water bodies.

MATERIALS AND METHODS

The studied water bodies (Vil'skiy, Zapasnyy, Verkhnevyksunsky, Varnavsky, Nizhniy ponds, Lake Lebedinka and Lake Malaya Lebedinka) are one of the largest reservoirs (with a surface area from 2.8 to 5.8 km^2) in the Nizhny Novgorod region, and are situated within the urban district of Vyksa. The city is located in the Prioksky lowland and is included in the Prioksky southwestern lowland territory of Polesye.

In 2017-2018, during the growing season, we conducted expeditionary surveys of these reservoirs. Algological samples were taken at 10 control stations. The location map of the sampling points is shown in Figure 1.

Sampling and laboratory investigation of phytoplankton samples were carried out according to generally accepted methods [2], [3], [6]. Phytoplankton samples were taken using Molchanov bathometer. All quantitative samples with a volume of 0.5 l were fixed with 4% solution of formalin. Fixed samples were concentrated in 2 stages, using the settling method, to 10−20 ml. Qualitative water samples were concentrated by direct filtration through the membrane filters in two stages — with pore diameters of 3–5 μm and 1.2–1.5 μm, and they were

studied in a living state [7], [8], [9], [10]. Also, during the period of research, the weather conditions and air temperature were recorded. When sampling, the temperature of water and the transparency by Secchi disk were measured.

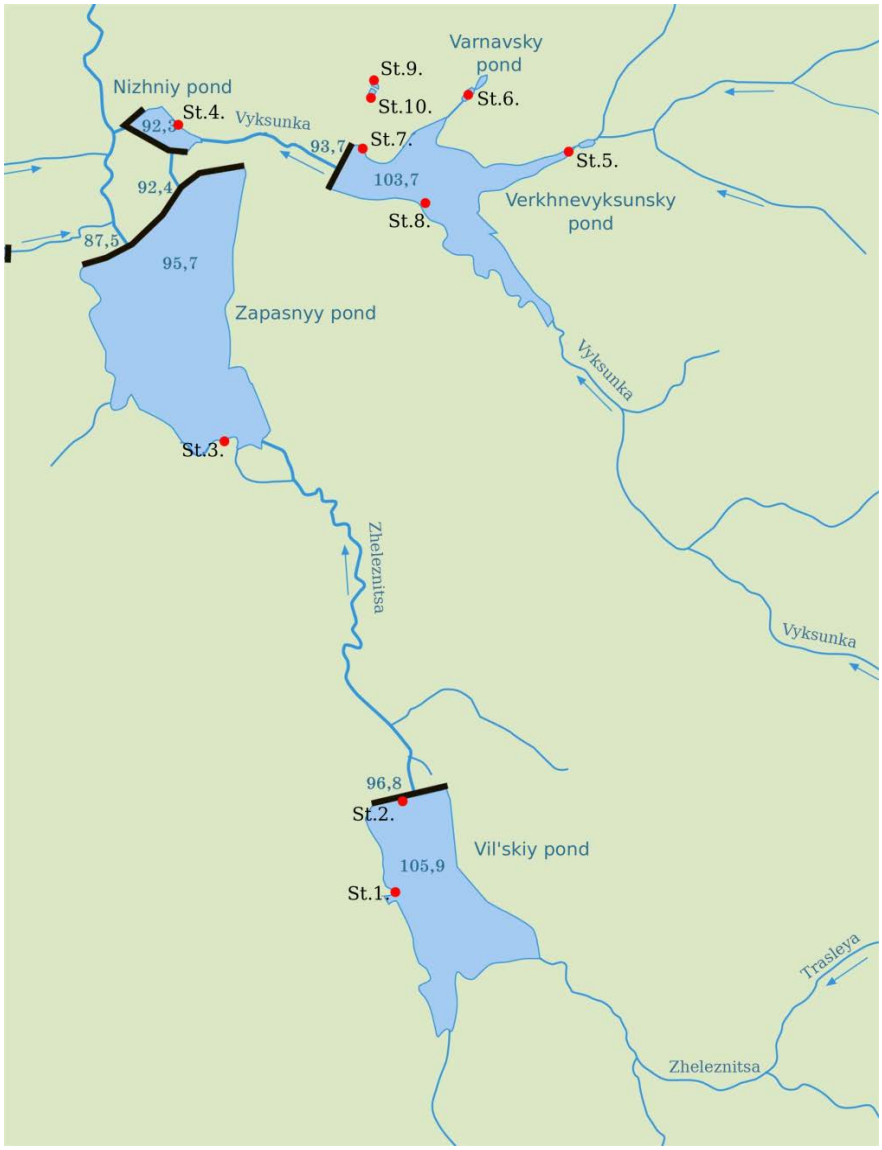


Fig. 1. The location map of the water quality sampling stations in the reservoirs, which are situated within the city of Vyksa.

56 quantitative and qualitative samples were collected in total. Species composition, abundance, and biomass were used to characterize the algal communities. The index of trophicity was calculated for each sample by the Milius block: Ib = 44.87 + 23.22 * logB [1]; and the Pantle–Buck saprobity index in the Sladechek modification for plankton communities was also estimated [4]. The dynamics of the general and relative species richness was studied in order to characterize the structural indicators of phytoplankton communities. The species with the abundance or biomass greater than or equal to 10% of the total values of indicators, were considered as dominant in the communities, for the subdominant species - 5-10%. Dominant complexes were distinguished on the basis of rank distribution by the abundance and biomass of species.

RESEARCH RESULTS

During the period of observation, 110 taxa were defined in the phytoplankton of the studied water bodies. The largest number of taxa was found among the diatoms (39.0%) and

green algae (36.6%) (Fig. 2). Among the other divisions, phytoplankton was represented by blue-green (7.31%) and euglena (17.1%) algae. The most frequent occurrence is typical for the species, belonging to the classes *Bacillariophyceae*, *Chlorophyceae*, and *Euglenophyceae*.

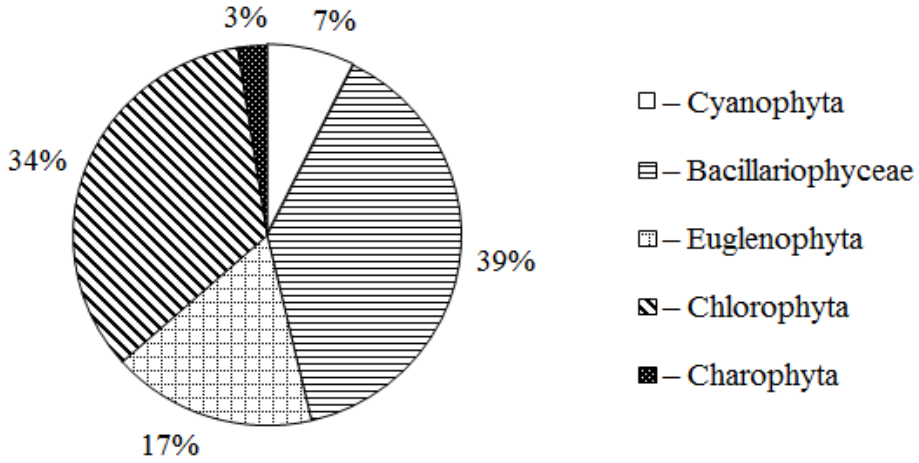


Fig. 2. The distribution of taxa (%) of algae in the reservoirs, located within the city of Vyksa (2017-2018).

The highest species diversity of algae is observed in the ponds, located on the river Zheleznitsa, at the stations 1 and 2 (Vil'skiy pond), where 21-23 species are occurred simultaneously. At the stations, located below (Nizhniy and Zapasnyy ponds), the species diversity increases to 30 species. In the samples from these reservoirs, diatoms and green algae predominate in the number of taxa.

The phytoplankton of ponds, located on the river Vyksunka, is less diverse. In this reservoir (the stations 5 - 8), diatoms algae dominate in the number of species.

53 species, belonging to blue-green, diatoms, green and euglena algae were found in the Nizhniy pond, in which all other water bodies flow.

In the small lakes Malaya Lebedinka (station 9) and Lebedinka (station 10), phytoplankton was represented only by 12-15 species of diatoms and euglena algae. The most frequent occurrence was typical for the euglena algae *Trachelomonas*, blue-green algae *Microcystis aeruginosa* Kutz., diatoms algae of the genera *Aulacoseira*, *Cyclotella*, species *Tabellaria fenestrata* (Lyngb.) Kütz., *Nitzschia palea* (Kütz).W.Sm., as well as green algae of the genera *Pediastrum*, *Scenedesmus*.

DISCUSSION OF THE RESULTS

According to the analysis of ecological and geographical characteristics of the algae species of plankton in the ponds of the city of Vyksa, in terms of the geographical distribution, the vast majority of taxa refer to the species with a wide geographical distribution. The main part of algae – the indicators of acidification of the environment – refers to indifferents. The significant number of algae, represented in the algal flora of plankton, is the indicators of organic pollution. Among them, the major part relates to mesosaprobes. The algae of the studied reservoirs are mainly represented by the phytoplankton species. At the same time, there are diatoms with a wide ecological spectrum, which can inhabit both plankton and benthos. There are also some taxa, requiring further identification at the level of specie.

The average abundance and biomass of algae in the ponds, located on the river Zheleznitsa were 37.3 million cells/l and 17.3 mg/l (Fig. 3, 4).

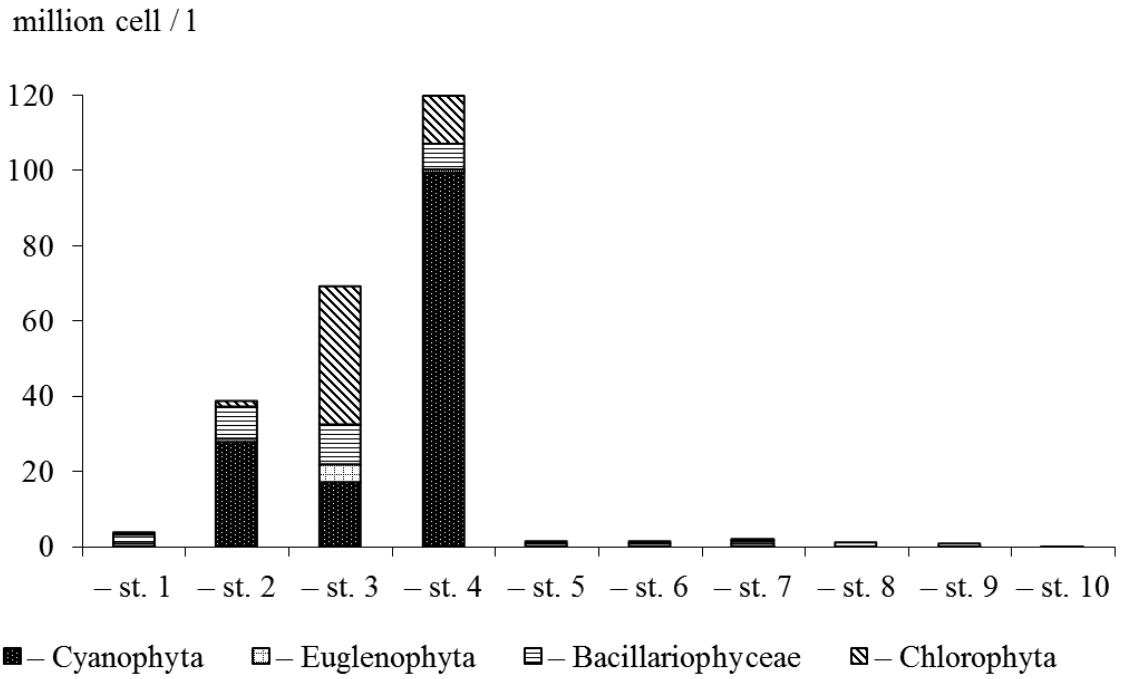


Fig. 3. The abundance of planktonic algae (million cell/l) in a number of reservoirs, located within the city of Vyksa (August 2017): the axis of abscissa shows the numbers of stations on the studied reservoirs.

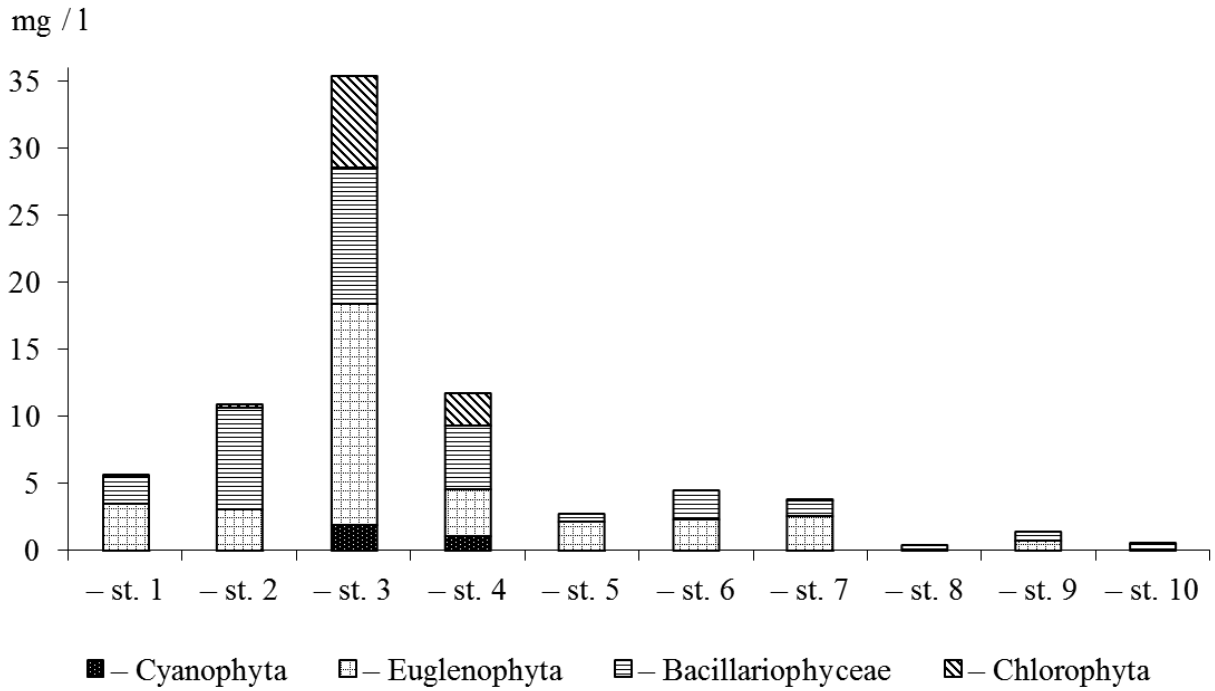


Fig. 4. The biomass of planktonic algae (mg/l) in a number of water bodies, located within the city of Vyksa (August 2017): the axis of abscissa shows the numbers of stations on the studied water bodies.

Among them, 32.8% of abundance and 2.3% of biomass were constituted by blue-green algae. There were also diatoms, which amounted to 33.9 and 44.9% of the abundance and biomass, euglena algae - 8.5 and 44.9%, and green algae - 24.8 and 8.0%, respectively. The phytoplankton of ponds, located on the river Vyksunka, is less abundant. Here, the average abundance and biomass were 1.44 million cells/l and 2.85 mg/l. In this water body, diatoms algae (33.1% of the abundance, 50.0% of biomass) and euglena algae (33.1 and 49.8%,

respectively) prevail. There are also blue-green and green algae. Their share in the percentage ratio doesn't exceed 0.1-3.0%.

During the period of research, "blooming" of water was observed, caused by blue-green algae, in the Nizhniy pond, where all other water bodies flow. The average abundance and biomass were 119.9 million cells/l and 11.8 mg/l, while 83.0% of the abundance and 9.0% of the biomass were constituted by blue-green algae. Diatoms (5.7 and 40.2%), euglena algae (0.7 and 29.7%) and green algae (10.6 and 21.1%) were also numerous.

In the lake Malaya Lebedinka, the abundance and biomass of algae were 0.93 million cells/l and 1.38 mg/l. Among them, 74.07% of the abundance and 47.32% of biomass were constituted by diatoms, and 25.93% of the abundance and 52.68% of biomass - by euglena. In the lake Lebedinka, the average abundance and biomass of algae are 0.11 million cells/l and 0.48 mg/l. Among them, 50.00% of the abundance and 99.23% of biomass are constituted by diatoms.

In terms of quantitative indicators, the following algae prevail among phytoplankton: division Cyanophyta: *Microcystis aeruginosa f. flos-aquae* (Wittr.) Elenk., *Aphanizomenon flos-aquae* (l.) Ralfs., *Oscillatoria planctonica* Wotosz., class *Bacillariophyceae: Aulacoseira italica* (Ehr.) Kiitz., *A. granulata* (Ehr.) Ralfs., *Nitzschia palea* (Kiitz).W.Sm., *Cyclotella meneghiniana* Kiitz., *Fragilaria construens* (Ehr.) Grun., *Tabellaria fenestrata* (Lyngb.) Kiitz., division Chlorophyta: *Scenedesmus* sp. sp. *Pediastrum boryanum* (Turp.) Menegh. and Euglenophyta: *Trachelomonas* sp. sp. (Table 1).

Table 1. The dominant complexes of planktonic algae in a number of reservoirs, located within the city of Vyksa (August 2017)

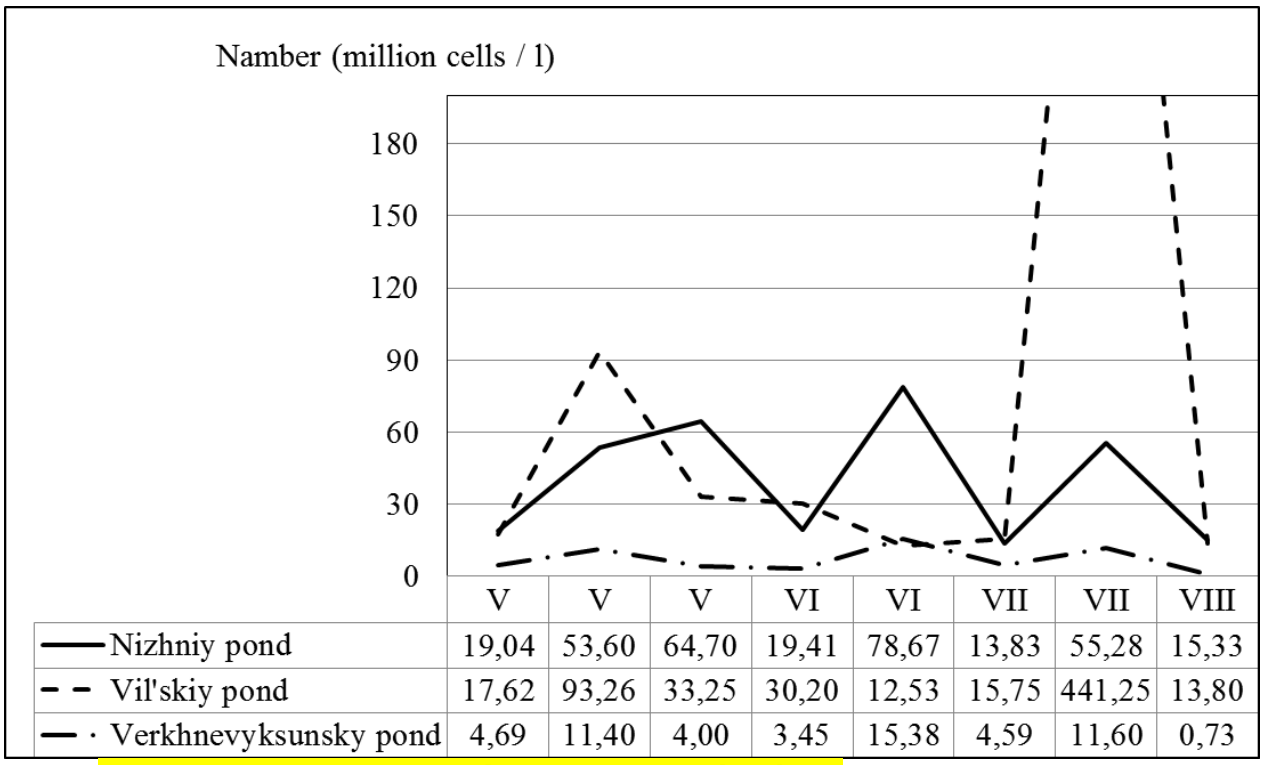
№	Water body	Dominant species
1	Vil'skiy pond (st. 1, 2).	*Aulacoseira italica* (Ehr.) Simonsen *Aulacoseira granulata* (Ehr.) Simonsen *Trachelomonas volvocina* (Ehr.) Ehr. *Nitzschia palea* (Kütz). W. Sm. *Scenedesmus denticulaus* Lagerheim (var. disciformis Hortobágyi) *Scenedesmus quadricauda* (Turp.) Bréb. *Pediastrum boryanum* (Turp.) Menegh. *Trachelomonas hispida* (Perty) Stein emend. Defl. *Microcystis aeruginosa* Kütz. *Trachelomonas horrida* Palmer. *Cyclotella meneghiniana* Kütz. *Euglena* sp. *Synedra ulna* (Nitzsch.) Ehr. *Oscillatoria planctonica* Wotosz. *Fragilaria construens* (Ehr.) Grun.

2	Zapasnyy pond (st. 3)	*Scenedesmus quadricauda* (Turp.) Breb. *Microcystis aeruginosa* Kütz. *Aulacoseira granulata* (Ehr.) Simonsen *Trachelomonas volvocina* (Ehr.) Ehr. *Nitzschia palea* (Kütz). W. Sm. *Pediastrum boryanum* (Turp.) Menegh. *Fragilaria construens* (Ehr.) Grun. *Coelastrum cambricum* Arch. *Aulacoseira italica* (Ehr.) Simonsen *Coelastrum proboscideum* Bohl. *Cyclotella meneghiniana* Kütz. *Trachelomonas intermedia* Dang. *Trachelomonas hispida* (Perty) Stein emend. Defl. *Tetraedron caudatum* (Corda.) Hansg. *Didimocystis planctonica* Korschikoff. *Trachelomonas horrida* Palmer. *Cyclotella comta* (Ehr.) Kütz.
3	Nizhniy pond (st. 4)	*Oscillatoria planctonica* Wotosz. *Scenedesmus quadricauda* (Turp.) Breb. *Microcystis aeruginosa* Kutz. *Nitzschia palea* (Kütz). W. Sm. *Pediastrum boryanum* (Turp.) Menegh. *Aulacoseira granulata* (Ehr.) Simonsen *Pediastrum duplex* Meyen. *Trachelomonas volvocina* (Ehr.) Ehr. *Scenedesmus falcatus* Chodat. *Aulacoseira italica* (Ehr.) Simonsen *Cyclotella meneghiniana* Kütz. *Asterionella formosa* Hass. *Trachelomonas intermedia* Dang. *Trachelomonas hispida* (Perty) Stein emend. Defl. *Achnanthes sp.* *Nitzschia holsatica* (Kütz). W. Sm.
4	Verkhnevyksunsky pond (st. 5, 6, 7, 8).	*Trachelomonas volvocina* (Ehr.) Ehr. *Aulacoseira granulata* (Ehr.) Ralfs. *Aulacoseira italica* (Ehr.) Simonsen *Aphanizomenon flos-aquae* (L.) Ralfs. *Tabellaria fenestrata* (Lyngb.) Kütz. *Cyclotella meneghiniana* Kütz. *Asterionella formosa* Hass. *Synedra ulna* (Nitzsch.) Ehr. *Cocconeis placentula* Ehr. *Microcystis aeruginosa* Kütz. *Trachelomonas intermedia* Dang.
5	Lake Malaya Lebedinka (st. 9)	*Aulacoseira granulata* (Ehr.) Simonsen *Aulacoseira italica* (Ehr.) Simonsen *Euglena viridis* Ehr. *Trachelomonas volvocina* (Ehr.) Ehr. *Trachelomonas intermedia* Dang.
6	Lake Lebedinka (st. 10).	*Cocconeis placentula* Ehr. *Monoraphidium arcuatum* (Korsch.) Hind.

During the growing period of 2018, the seasonal dynamics of the quantitative indicators of planktonic algae in a number of ponds, located within the city of Vyksa, was studied. The reason is that the single-shot irregular analyzes of water are uninformative, and based on them it is difficult to assess the state of the reservoir. For this purpose, the observations and water sampling were conducted at the Verkhnevyksunsky pond, located on the river Vyksunka, on the Vil'skiy pond, located on the river Zheleznitsa, as well as on the Nizhniy pond, where all other water bodies flow.

The highest values of the abundance and biomass during the period of research were defined for the Vil'skiy pond. The total abundance and biomass here ranged from 12.5 - 441.3 million cells/l and 15.4 - 116.4 mg/l (Fig. 5-8). The average values of the abundance and biomass of algae for the season was 82.2 ± 52.1 million cells/l and 40.4 ± 11.9 mg/l. In early summer, the diatom complex of algae dominated in the reservoir. The following species prevailed: *Aulacoseira granulata, A. italica, Melosira varians, Stephanodiscus hantzschii, Asterionella formosa, Navicula* sp., *Nitzschia palea, Synedra ulna.* From the second half of summer, “blooming” in the pond was periodically caused by the blue-green algae *Oscillatoria* sp., *Microcystis aeruginosa, Aphanizomenon flos-aquae*. Also in the second half of summer, the green algae of the species *Pediastrum duplex, Coelastrum proboscideum, Scenedesmus guadricauda, Chlamydomonas* sp. were subdominant. Periodically, the increase in the content of dinophytes algae *Peridinium,* euglena algae *Trachelomonas* and cryptophytic algae *Cryptomonas ovata* was observed in water.

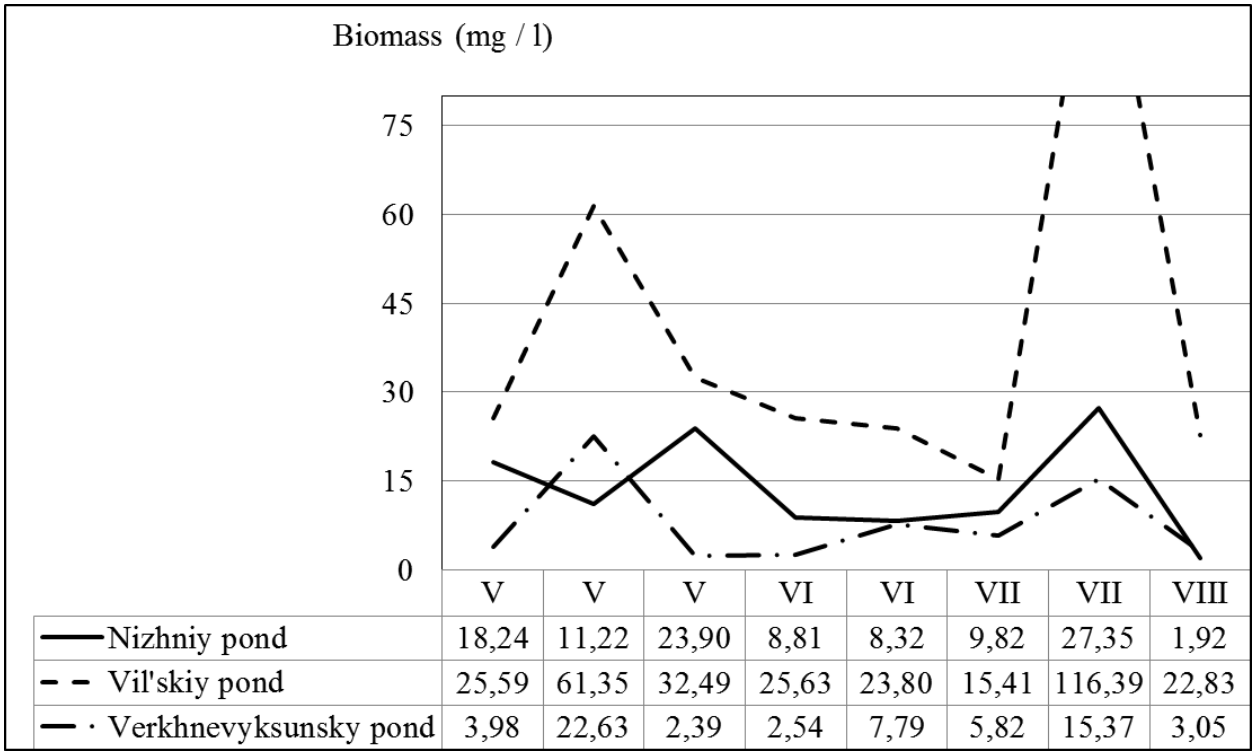
The lowest values of the abundance and biomass, during the period of study, were defined for the Verkhnevyksunsky pond. The total abundance and biomass varied between 0.7 - 15.4 million cells/l and 2.4 - 22.6 mg/l (Fig. 5-8). The average abundance and biomass of algae were 7.0 ± 1.8 million cells/l and 8.0 ± 2.6 mg/l. During the entire period of research, the dominant complex consisted of diatoms and green algae in equal shares: *Aulacoseira granulata, A. italica, Navicula* sp., *Asterionella formosa, Nitzschia palea, Synedra ulna, Diatoma vulgare, Dictyosphaerium pulchellum, Scenedesmus guadricauda, Coelastrum proboscideum, Crucigenia tetrapedia*.



	V	V	V	VI	VI	VII	VII	VIII
Nizhniy pond	19,04	53,60	64,70	19,41	78,67	13,83	55,28	15,33
Vil'skiy pond	17,62	93,26	33,25	30,20	12,53	15,75	441,25	13,80
Verkhnevyksunsky pond	4,69	11,40	4,00	3,45	15,38	4,59	11,60	0,73

Замечание по рисунку! Number заменить на abundance

Fig. 5. Seasonal dynamics of the total abundance of planktonic algae (million cells/l) in the reservoirs, located within the city of Vyksa (2018).



	V	V	V	VI	VI	VII	VII	VIII
Nizhniy pond	18,24	11,22	23,90	8,81	8,32	9,82	27,35	1,92
Vil'skiy pond	25,59	61,35	32,49	25,63	23,80	15,41	116,39	22,83
Verkhnevyksunsky pond	3,98	22,63	2,39	2,54	7,79	5,82	15,37	3,05

Fig. 6. Seasonal dynamics of the total biomass of planktonic algae (mg/l) in the water bodies, located within the city of Vyksa (2018).

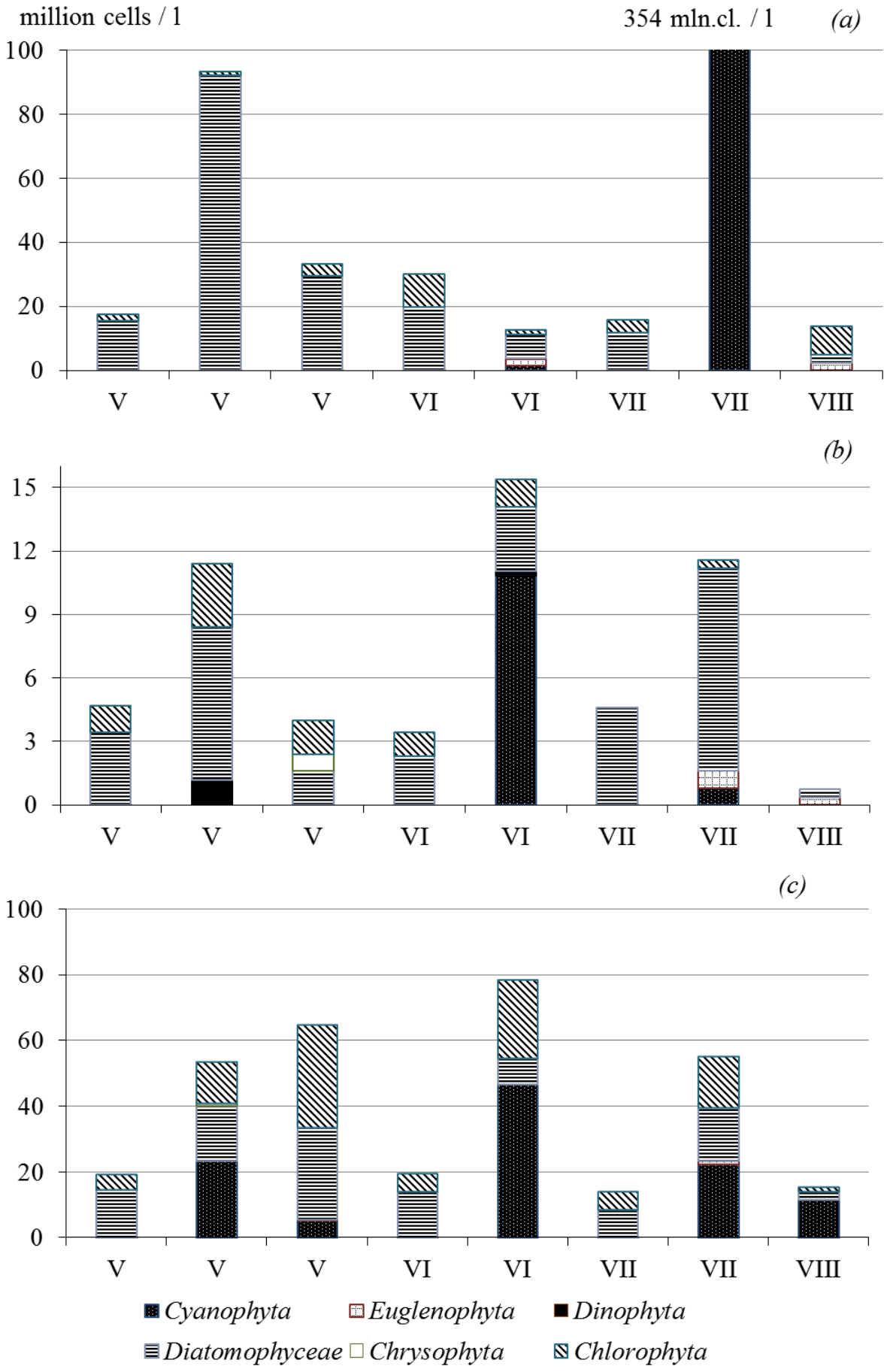


Fig. 7. The abundance of planktonic algae (million cells/l) in the reservoirs, located within the city of Vyksa (2018): a - Vil'skiy pond, b - Verkhnevyksunsky pond, c - Nizhniy pond.

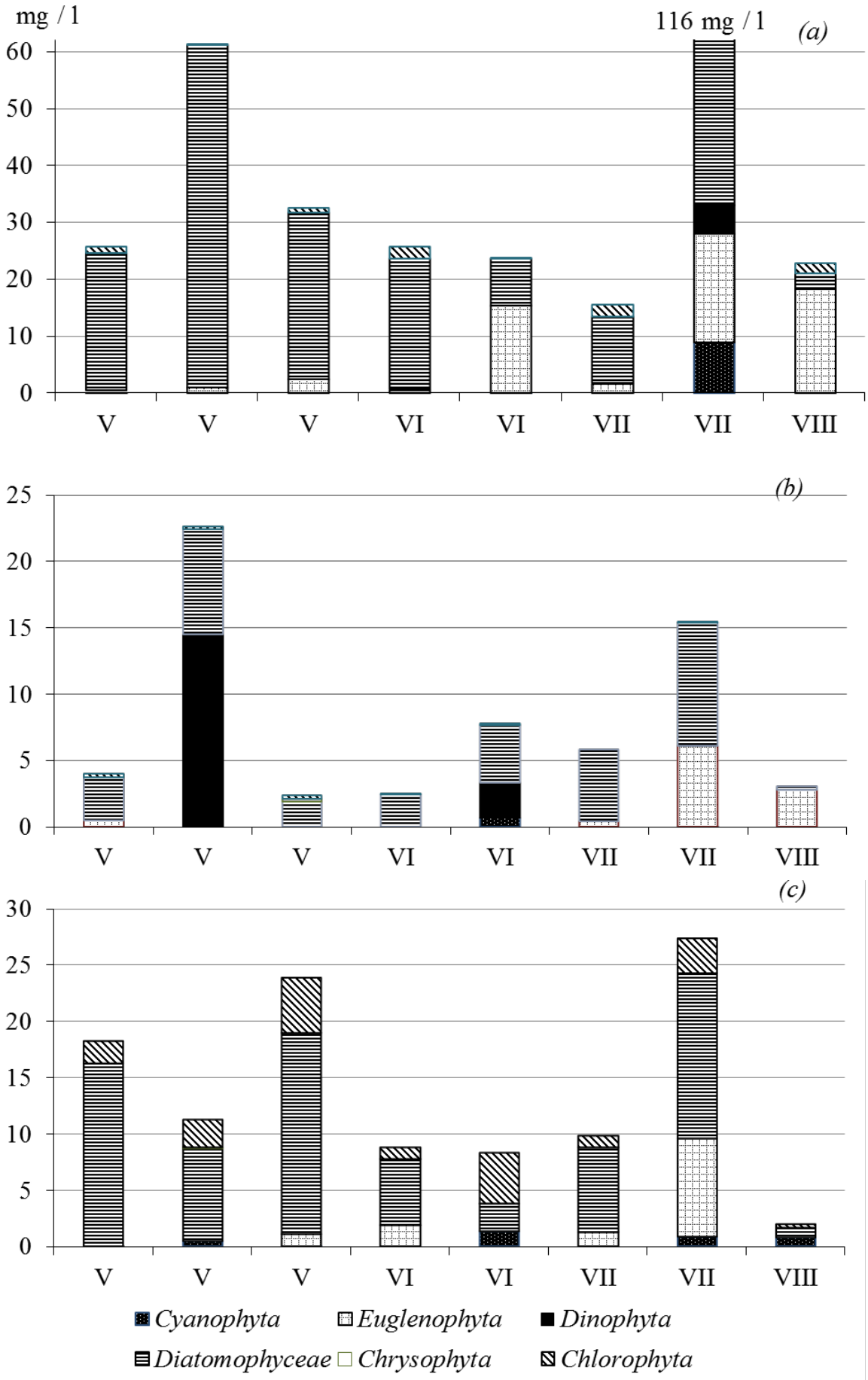
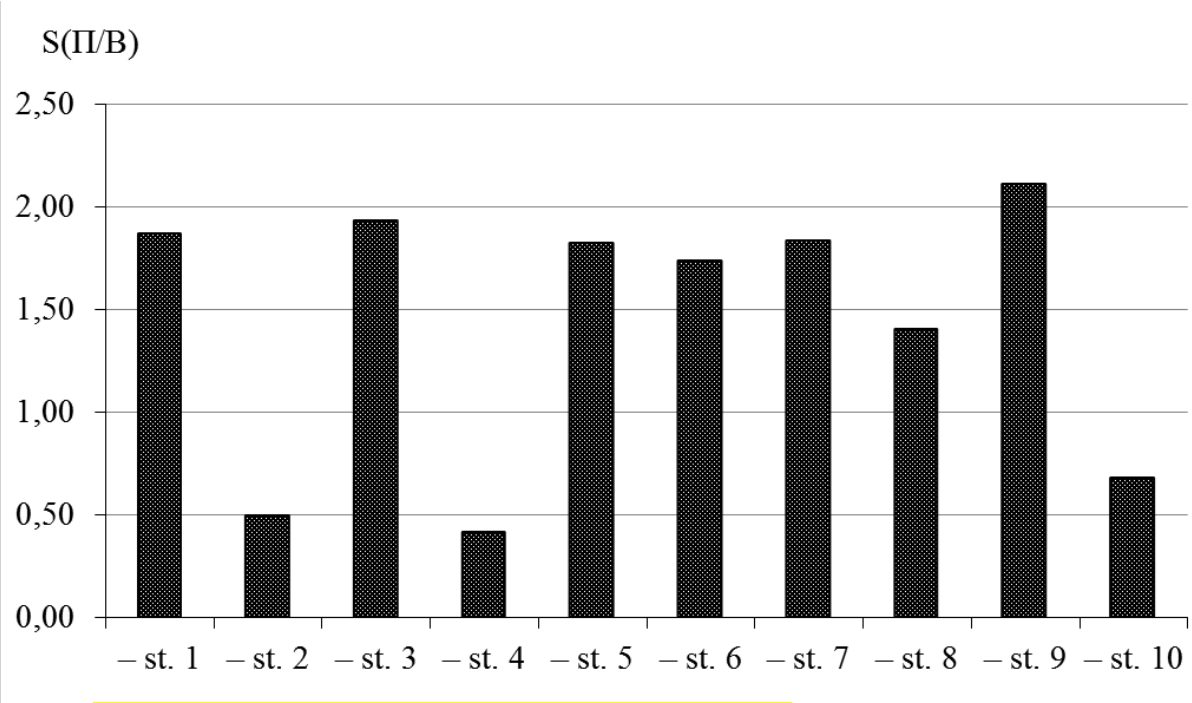


Fig. 8. The biomass of planktonic algae (mg/l) in the water bodies, located within the city of Vyksa (2018): a - Vil'skiy pond, b - Verkhnevyksunsky pond, c - Nizhniy pond.

In the second half of summer, there were short-time outbreaks of development of the blue-green algae *Microcystis aeruginosa*. Also in August, the euglena algae of the genus *Trachelomonas* were observed among the subdominants. On some dates, the species of dinophytes, related to the genera *Peridinium*, became quite numerous.

Despite the fact, that all other water courses flow into the Nizhniy pond and it is located at the very bottom of the stream, this reservoir is not the most polluted, according to the indicators of phytoplankton. Here, the quantitative indices of algae and trophic indices are significantly lower, than in the Vil'skiy pond. The total abundance and biomass vary between 13.8 - 78.7 million cells/l and 1.9 - 27.4 mg/l (Fig. 5-8). The average abundance and biomass of algae during the study period were 40. ± 9.1 million cells/l and 13.7 ± 3.1 mg/l. In this reservoir, the dominant complex consists of diatoms, green and blue-green algae. The following species are the most numerous among the diatoms: *Aulacoseira italica*, *Melosira varians*, *Nitzschia palea*, *Diatoma vulgare*, *Asterionella formosa.* Such species as *Scenedesmus guadricauda*, *Carteria globosa*, *Dictyosphaerium pulchellum*, *Chlamydomonas* sp., *Coelastrum cambricum*, *Pediastrum* sp. sp. predominate among the green algae. During the summer, the blue-green algae breed in large quantities in this pond, and periodically cause the “blooming” of water by such species as *Microcystis aeruginosa*, *Oscillatoria planctonica*, *Aphanizomenon flos-aquae*, *Anabaena scheremetievi.* The high content of euglena algae of the genus *Trachelomonas* and *Euglena* is also observed in this reservoir.

The indicators of quantitative development of phytoplankton are widely used in order to characterize the state and trophic status of water bodies. To determine the degree of saprobity of the reservoir, the Pantle–Buck saprobity index in the Sladechek modification (S, P/B) was calculated on the basis of the phytoplankton biomass (Fig. 9-10).



Замечание по рисунку! S(П/В) заменить на S (P/B)

Fig. 9. The indices of saprobity S (P/B) of the reservoirs, located within the city of Vyksa (August 2017): the axis of abscissa shows the numbers of stations on the studied reservoirs.

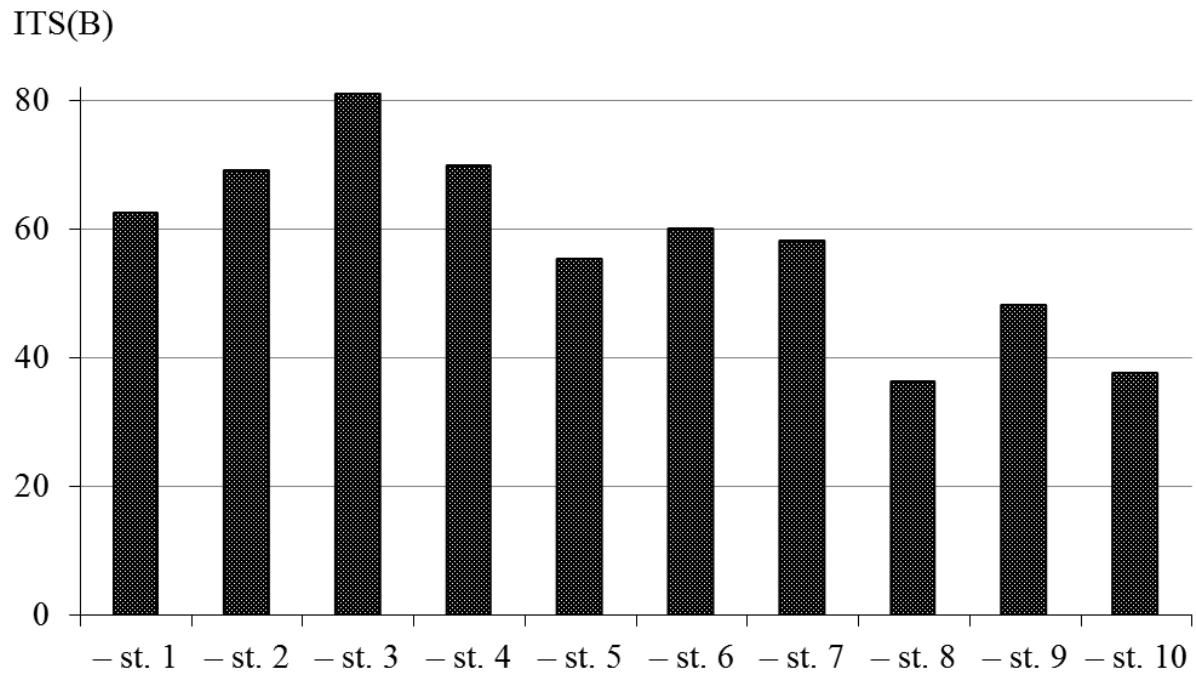


Fig. 10. The trophic indices (ITS) of the water bodies, located within the city of Vyksa (August 2017): the axis of abscissa shows the numbers of stations on the studied reservoirs.

According to the calculations, the quality of water in most of the studied reservoirs is estimated as mesosaprobic, and only at some stations – as oligosaprobic. The trophic indices, calculated on the basis of the Milius block [1] for the assessment of trophic status of the reservoirs, characterize these water bodies as mesotrophic for the most part.

According to the results of research of the seasonal dynamics of ponds in 2018 (Vil'skiy, Nizhniy and Verkhnevyksunsky ponds), during most of the growing season, these water bodies belong to β-mesosaprobic type and correspond to a moderately polluted zone (1.51-2.50). The highest values of the saprobity index are typical for the Vil'skiy pond. Considering the composition of the dominant complex, it can be said, that this reservoir is significantly polluted, and it is slow flow. During the summer, the quality of water remains rather low. Flagellate cryptophytes, dinophytes and green algae prevail in the pond. They prefer water bodies with organic pollution. The indicators of trophic status also characterize the reservoir as eutrophic, and in some periods – as hypereutrophic. The values of the trophic index range from 72.45 to 92.84.

According to the trophic index, the Verkhnevyksunsky pond is the most prosperous among the studied reservoirs. The trophic status of this water body in the studied area mostly corresponds to the mesotrophic type, and only sometimes - to eutrophic. The values of the trophic index range from 53.66 to 76.32.

Contrary to the assumptions, the Nizhniy pond is in a satisfactory condition. The values of the trophic indices during the summer were in the range 51.47-78.24, the water quality corresponded to the mesotrophic and eutrophic type.

Such different indicators of trophicity of the studied reservoirs are explained by their heterogeneity and location, as well as by the features of the streams, which flow into these ponds.

SUMMARY

The phytoplankton of the studied water bodies, located within the city of Vyksa, is formed by diatoms, green, blue-green and euglena algae. The highest values of the abundance and biomass are typical for the Vil'skiy pond. The lowest values of the abundance and biomass are observed in the Verkhnevyksunsky pond. The quality of water in most of the studied reservoirs was estimated as mesosaprobic. According to the indicators of water trophicity, most

of the studied objects are mesotrophic. The highest values of the indices of saprobity and trophicity were defined in the Vil'skiy pond, the water quality of which corresponded to the eutrophic and hypereutrophic type.

CONCLUSIONS

To identify a complete list of the species composition and structural features of the algal flora of water bodies, located within the city of Vyksa, it is necessary to conduct multiple seasonal investigations with repeated analyzes. Nevertheless, the obtained data can be applied in the long-term monitoring and prognostic research of the biodiversity and the state of water bodies in the Russian Federation. The study of biology and structure of phytoplankton communities in aquatic ecosystems is the basis for monitoring and control the quality of natural waters.

ACKNOWLEDGEMENTS:

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

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