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The abundance and seasonal dynamics of phytoplankton community of the middle course part of Hrazdan River in 2018

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Seasonal studies of phytoplankton community in the middle course part of Hrazdan River were performed in 2018. Eighty species of algae from 6 groups were identified. Diatoms were the dominant and Cyanophytas – subdominant group of the river's phytoplankton community. Maximum abundance of algae was registered in autumn. The river is considered "moderately polluted" according to the Shannon – Weaver water quality index and mainly "beta-mesosaprobic" based on the level of organic pollution according to the saprobic index.

Keywords: Hrazdan River, phytoplankton community, abundance, water quality, saprobity index.

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Introduction

Lake Sevan is the biggest freshwater waterbody in the Caucasus region. Hrazdan River is the only outlet of Lake Sevan. The length of the river is 141 km, the catchment basin area is 2560 km^2 (Chilingaryan et al., 2002). Hrazdan River has a great importance for the development of the economy of Republic of Armenia. There are numerous hydropower plants, irrigation systems and two reservoirs – "Akhpara" and "Yerevanyan lich" built on the Hrazdan River. As a result, the natural resources of Hrazdan hydroecosystem are under anthropogenic pressure and subject to heavy pollution in its catchment basin's area.

Changes in the ecological state of freshwater ecosystems under anthropogenic impact first of all caused the structural changes of the quantitative and qualitative parameters in the aquatic organisms' communities (Hassett and Jennett, 1981). Being the key element of the food web, phytoplankton is most responsive to the external factors. Both the qualitative and quantitative parameters determine the indicator properties of phytoplankton (Swaminathan, 2003).

The aim of the study is to evaluate seasonal dynamic of abundance, biomass, and species composition of algae as well as to assess water quality using bio indication methods.

Material and methods

Seasonal field campaigns at four stations located in the middle course part of Hrazdan River were carried in 2018 (Fig. 1.). Sampling site 1 was located downstream from Akhpara reservoir; sample site 2 – upstream from Bjni village; sampling site 3 – downstream from Bjni village; sampling site 4 – in Arzni village. Samples were collected from the water surface layer once per month in May, August and November.

The analyses of phytoplankton parameters were done by the standard methods accepted in hydrobiological studies. For the phytoplankton study 1 liter of water sample taken from each site was fixed with 40% formaldehyde solution (0.4% final concentration) immediately and stored at a dark place using sedimentation method. The further study was carried out under laboratory conditions according to Abakumov (1983).

Fig. 1. Map of the sampling sites. 1 – sampling site located downstream from Akhpara reservoir; 2 – sampling site located upstream from Bjni village; 3 – sampling site located downstream from Bjni village; 4 – sampling site located in Arzni village.

Quantitative and qualitative phytoplankton analyses were performed using microscope in the Nageotte chamber (V = 0.1 ml). Biomass was calculated with the cell volume measurement method.

Planktonic algae species were identified using keys and guides for freshwater systems (Hambaryan and Shahazizyan, 2014; Proshkina-Lavrenko and Makarova, 1968; Streble and Krauter, 2001; Tsarenko, 1990).

Frequency of occurrence was calculated (Jurcev, 1968). Water quality assessments were performed using biodiversity or Shannon – Weaver diversity (Shannon and Weaver, 1949) and saprobic indices (Pantle and Buck, 1955).

Results and discussion

Eighty species from six groups – Bacillariophyta, Chlorophyta, Cyanophyta, Euglenophyta, Dinophyta, Xanthophyta were identified (Table 1).

Bacillariophyta and Cyanophyta were the most abundant algae groups in the studied part of Hrazdan River. Species of Chlorophyta, Euglenophyta, Dinophyta and Xanthophyta were found in smaller proportions (Fig. 2).

Similar to previous years diatomic algae dominated quantitatively and qualitatively in 2018 (Fig. 2), which can be considered typical for Sevan basin rivers (Khachikyan et al., 2017a, b; Khachikyan and Stepanyan, 2018; Stepanyan and Hambaryan, 2016a; Stepanyan et al., 2017).

The following species: *Melosira varians* Ag., 1827, *M. granulata* Ralfs (1861), *Fragilaria capucina* Desmazières (1830), *F. crotonensis* Kitton (1869), *Amphora ovalis* Kützing (1844), *Cocconeis placentula* Ehrenberg (1838), *Gomphonema olivaceum* Brébisson (1838) and centric species *Stephanodiscus astraea* Grunow (1880) and *Cyclotella comta* Kützing (1849) – formed the biggest share of diatomic algae in terms of both abundance and biomass in the phytoplankton community of the middle course of the river.

The blue-green algae (Cyanophyta, cyanobacteria) were the subdominant group in the phytoplankton community of the studied section. The common species in the river were small-cell species of coccoid cyanobacteria colony forms such as *Aphanothece clathrata* West (1906), *Microcystis aeruginosa* Kützing (1846) and *M. wesenbergii* Komárek in Joosen (2006). During the study period these species were found in all seasons and at all sampling sites. The filamentous forms such as *Oscillatoria limnetica* Lemmermann (1900) and *O. chlorina* Kützing ex Gomont (1892) were registered in summer and autumn. Presence of these species is typical for waters with high nutrient concentrations (Vilalta et al, 2003).

The prevailing species from Chlorophyta group in the middle course of Hrazdan River was the big colonial *Oocystis solitaria* Wittrock et Nordstedt (1879). High diversity was registered for genus *Characium* A. Br. which was represented by four species.

The dominant species belonging to the Euglenophyta were represented by *Trachelomonas volvocina* Ehrenberg (1834) and *T. hispida* F. Stein (1878). In addition, *Euglena viridis* Ehrenberg (1830) was registered in the river for the first time.

Table 1. Species list, saprobity (*S*) and frequency of occurrence of phytoplankton species of the middle stream of Hrazdan River in 2018 (+ + + – species were found in spring, summer and autumn).

	Phytoplankton species	Sampling site 1	2	3	4	*S*	Frequency, %
Cyanophyta	*Aphanothece clathrata* W. West et G.S. West	+ + +	+ + +	+ + +	+ + +	β	100
	Microcystis aeruginosa Kutzing	+ + +	+ + +	+ + +	+ + +	o-α	100
	M. wesenbergii Komárek in Joosen	+ + +	+ + +	+ + +	+ + +	o-α	100
	Dactylococcopsis raphidioides Hansgirg	– – –	– – –	+ – –	– – –	–	8
	Oscillatoria limnetica Lemmermann	– + –	– – –	– – –	– – –	o-β	8
	Oscillatoria chlorina Kützing ex Gomont	– – +	– – –	– – –	– – –	p	8
	Pleurocapsa sp.	– – –	– – –	– + –	– – –	–	8
Bacillariophyta	*Achnanthes minutissima* Kützing	– – –	– – –	– – –	+ – –	β	8
	Amphora ovalis (Kützing) Kützing	+ + +	– + +	+ + –	+ + +	α-β	83
	Ceratoneis arcus (Ehrenberg) Kützing	+ + –	– – –	– – –	+ – –	o-x	25
	Cocconeis placentula Ehrenberg	+ + +	+ + –	+ + +	+ + +	o-β	92
	C. pediculus Ehrenberg	– – –	– – –	– + –	– + –	o-α	16
	Cyclotella comta Kützing	+ + +	– – +	– – +	– – –	β-o	42
	C. stelligera (Cleve et Grunow) Van Heurck	– + +	– – –	– – –	– – –	x	16
	C. kuetzingiana Thwaites	– – –	– – –	– – +	– – –	β	8
	C. radiosa (Grunow) Lemmermann	– – –	– + –	– – –	– – –	β	8
	Cymbella ventricosa C. Agardh	+ + +	– – –	+ – +	+ – –	o-β	50
	C. prostrata (Berkeley) Cleve	– + –	– – –	– – –	– – +	o-α	16
	C. helvetica Kützing	– – –	– + –	– – –	– – –	o-α	8
	C. parva (W. Smith) Kirchner	– – –	– – –	– – +	– – –	–	8
	C. affinies Kützing	– – –	– – –	– – –	– + –	β-o	8
	Cymatopleura solea (Brébisson) W. Smith	– + –	– – –	– – –	– – –	o	8
	Diatoma hiemale var. *hiemale* (Roth) Heib.	+ + +	– – –	– + +	+ – +	β-o	58
	D. hiemale var. *mesodon* (Ehrb.) Grun.	– + +	– – –	– – –	+ + –	o-β	33
	D. vulgaris Bory	– + –	– + –	– – +	+ – –	β	33
	Diploneis ovalis (Hilse) Cleve	– + –	– – –	– – –	– – –	β	8
	Epithemia sorex Kützing	– – +	– – –	+ – –	– – –	o-α	16

	Phytoplankton species	1	2	3	4	*S*	Frequency, %
Bacillariophyta	*Fragilaria capucina* Desmazières	+ + +	– + –	+ – +	+ + +	o	75
	F. construens (Ehrenberg) Grunow	– + –	– – –	– – +	+ + +	o	42
	F. crotonensis Kitton	+ + +	– – –	– – –	+ – –	α-β	33
	Gomphonema olivaceum (Hornemann) Brébisson	– – +	+ – –	– + +	– – +	β-α	42
	G. constrictum Ehrenberg in Kützing	+ – +	– – –	– – +	+ – +	o	42
	G. angustatum (Kützing) Rabenhorst	– + –	– – –	– – –	– – –	β	8
	G. parvulum (Kützing) Kützing	– – –	– – –	– + –	– + –	x	16
	Melosira varians C. Agardh	+ + +	– + +	+ – +	+ – +	α-β	75
	M. granulata (Ehrenberg) Ralfs	– + –	– – –	+ – –	– – –	α-β	16
	Nitzschia palea (Kützing) W. Smith	+ – –	– – –	– – –	+ – –	o-x	16
	N.amphibia Grunow	– – –	– – –	– – –	+ – +	o	16
	N. acicularis (Kützing) W. Smith	– + –	– –	– – –	– – +	o-β	16
	N. dissipata (Kützing) Rabenhorst	– – +	– – –	– – –	– – +	x	16
	Navicula cryptocephala Kutz.	+ + –	– + +	– – +	+ – +	x-o	58
	N. radiosa Kutz.	– + –	– – –	+ – –	+ – –	o	25
	N. hungarica Grunow	+ – –	– – –	– – +	– – +	α-β	25
	N. pupula Kützing	+ – –	– + –	+ – –	+ – +	x-o	42
	N. dicephala Ehrenberg	– – –	– – –	– – –	– – +	o-α	8
	Neidium productum (W. Smith) Cleve	– – –	– – –	+ – –	– – –	o-β	8
	Pinnularia virdis (Nitzsch) Ehrenberg	+ + –	– + –	+ – +	+ – +	o-x	58
	P. borealis Ehrenberg	– – –	– – –	– – –	+ – –	o-β	8
	P. leptosoma (Grunow) Cleve	+ – –	– – –	– – –	– – +	o	16
	P. subcapitata W. Gregory	– + –	– – –	– – –	– – –	x-o	8
	P. mesolepta (Ehrenberg) W. Smith	– – –	– + –	– – –	– – –	o-x	8
	P. fasciata (Lagerstedt) Hustedt	– – –	– – –	– – –	– + +	–	16
	Pinnularia sp.	– – +	– – –	– – –	– – –	–	8
	Rhoicosphenia curvata (Kützing) Grunow	+ – +	– + +	+ + –	+ + +	x-o	75
	Stephanodiscus hantzschii Grunow in Cleve et Grunow	– + –	– – –	– – –	– – –	α-β	8
	S. astraea (Kützing) Grunow	+ + +	+ + +	+ – +	+ – –	β	75

	Phytoplankton species	1	2	3	4	*S*	Frequency, %
Bacillariophyta	*Surirella robusta* Ehrenberg	– – +	– + –	– – –	– + +	β-o	33
	S. angustata Hustedt	+ – +	– – –	+ – –	+ – –	β	33
	S. ovata Kützing	– – –	– – –	– – –	+ – –	o-α	8
Chlorophyta	*Ankistrodesmus acicularis* (Braun) Korshikov	– – –	– – –	– – +	– + –	β	16
	A. angustus C. Bernard	– – –	– – –	– – +	– – –	–	8
	Ankyra ancora (G.M. Smith) Fott	– + –	– – –	– – –	– – –	β	8
	Characium naegelii A. Braun	– – +	– – –	– + –	+ – –	–	25
	C. nasutum Rabenhorst	– – +	– – –	– – –	– – –	–	8
	C acuminatum A. Braun in Kützing	– – +	– – –	– – –	– – –	–	8
	C. sieboldii A. Braun in Kützing	– – +	– – –	– – –	– – –	–	8
	Dictyosphaerium pulchellum H.C. Wood	+ + –	– – –	– – –	– – –	β	16
	Chlamydomonas reinhardtii P.A. Dangeard	– + –	– – –	– – –	– – –	α	8
	Oocystis solitaria Wittrock in Wittrock et Nordstedt	– + –	– – –	– – –	– – –	β-o	8
	Gloeocystis rupestris Rabenhorst	– + –	– – –	– – –	– – –	–	8
	Selenastrum gracile Reinsch	– + –	– – –	– – –	– – –	o-α	8
	S. bibraianum Reinsch	– – –	– – –	– – –	+ – –	β	8
Euglenophyta	*Trachelomonas volvocina* (Ehrenberg) Ehrenberg	+ + +	– – +	– + +	– + +	β	83
	T. hispida (Perty) F. Stein	+ – –	– – –	– – +	– – +	β	25
	T. oblonga Lemmermann	– + –	– – –	– – –	– – –	β-α	8
	Euglena viridis (O.F. Müller) Ehrenberg	– – –	– – –	– – +	– – –	–	8
Dinophyta	*Peridinium willei* Huitfeldt-Kaas	+ – –	– – –	– – –	– – –	o-β	8
Xanthophyta	*Tribonema monochloron* Pascher et Geitler in Pascher	– – –	– – –	– – +	+ – –	–	16
	Characiopsis minuta (A. Braun) Borzì	– + –	– – –	– – –	– – –	–	8

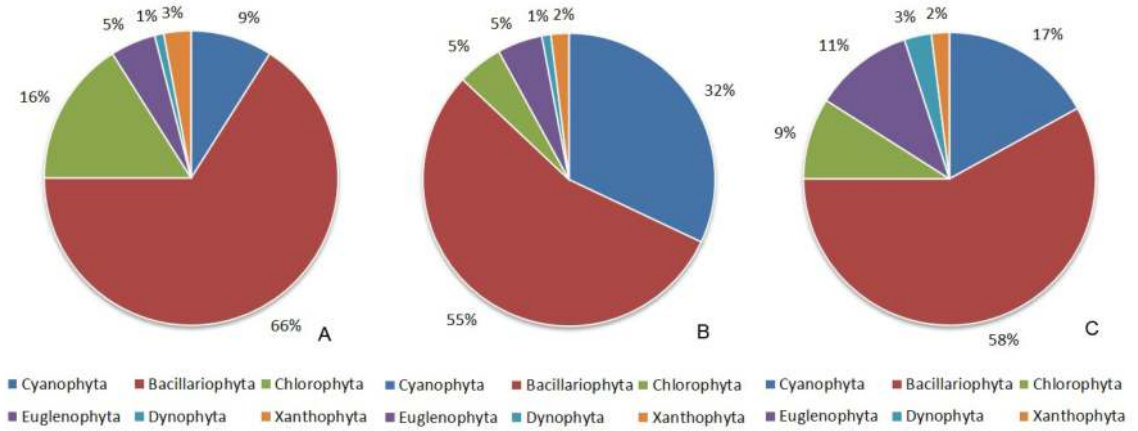

Fig. 2. The percentage of different groups of phytoplankton community of the middle course part of Hrazdan River in 2018. A – species composition; B – abundance; C – biomass.

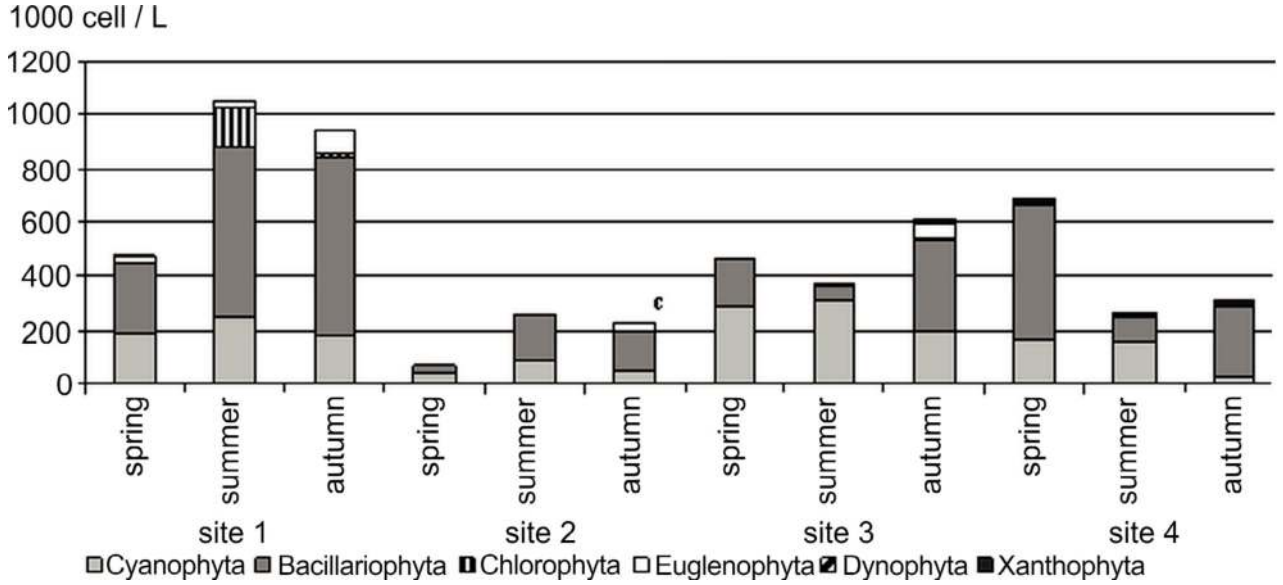

Fig. 3. Seasonal dynamics of algae abundance of the middle course of Hrazdan River in 2018.

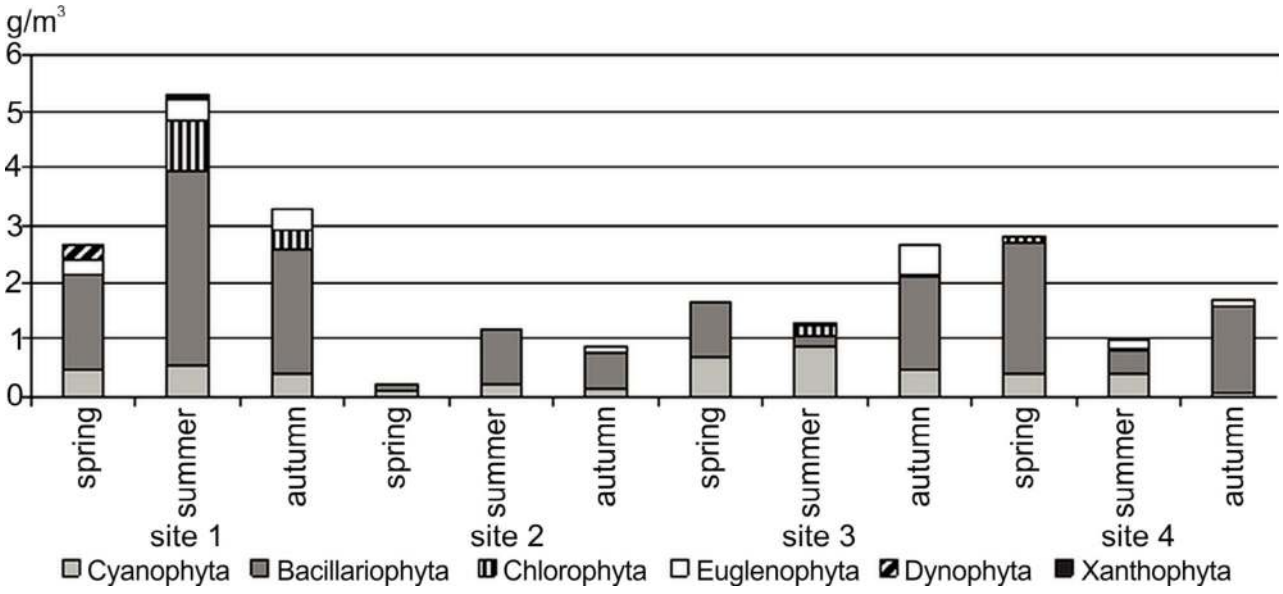

Fig. 4. Seasonal dynamics of algae biomass of the middle course of Hrazdan River in 2018.

Dynophyta (one genus – *Peridinium* Ehrenberg) and Xantophyta (two genera – *Characiopsis* Borzi and *Tribonema* Derbes et Solier) possessed lower diversity in the river.

Only 14 species (17% from total) had a frequency higher than 50% in the investigated part of Hrazdan River. Sixty-four species (79%) indicated organic pollution. According to the data in Table 1, the beta-mezosaprobic species prevailed in the phytoplankton community.

Algae abundance increased in the river from spring – 1 700 000 cell/L to autumn – 2 090 000 cell/L during study period. The highest biomass of phytoplankton (8.76 g/m^3) was registered in summer.

In spring the lowest quantity of algae by abundance (68 000 cell/L) and biomass (0.22 g/m^3) was registered in the site 2, the highest abundance (620 000 cell/L) was found in the site 4 (Fig. 3). Diatomic algae dominated in three observation points (sites 1, 2 and 3). High abundance of diatoms was due to quntitative development of *Fragilaria capucina* (70 000 cell/L), *Melosira varians* (60 000 cell/L) and *Amphora ovalis* (52 000 cell/L) species. Blue-green algae *Aphanothece clathrata* predominated (224 000 cell/L) in the site 3. The maximum biomass (2.66 g/m^3) was registered in the station 4 (Fig. 4). It was result of development of big cell species such as *Peridinium willei* Huitfeldt-Kaas (1900)*, Trachelomonas volvocina* and *T. hispida*.

The Shannon-Weaver diversity index was within a range of 1.65 to 2.95. Saprobic index varied from 1.56 to 1.82 and reflected the oligo-to beta- mesosaprobic zones (Table 2).

The abundance of algae was increased at the site 1 in summer. High numbers were registered for all groups of phytoplankton community. Diatoms dominated in the phytoplankton community by 60% of the total abundance and 64% of the total biomass, due to mass development of *Stephanodiscus astraea* and *Melosira granulate* species. According to the previous studies the species of genera *Stephanodiscus* and *Melosira* also dominated in the Akhpara reservoir during the summer (Stepanyan and Hambaryan, 2016b).

Blue-green algae were the subdominant group in terms of abundance. Maximum quantitative development was found for *Aphanothece clathrata* – 116 000 cell/L and 0.26 g/m^3. High quantities was also recorded for *Oscillatoria limnetica* – 80 000 cell/L and 0.12 g/m^3.

Fairly high abundance was registered for Chlorophyta in summer (Fig. 3). This is not typical for Hrazdan River (Hambaryan and Stepanyan, 2014; Stepanyan and Hambaryan, 2016a). The high quantitative values of green algae were the result of development of *Oocystis solitaria* Wittrock et Nordstedt (1879) – 108 000 cell/L and 0.62 g/m^3. It is important to mention that in this period *Oocystis solitaria* dominated also in Lake Sevan, and it could be due to the species' spatial transfer from lake to river system (Annual report of the Institute of Hydroecology and Ichthiology, 2018).

Abundance and biomass values of algae became lower downstream by the river course in site 2 (Fig. 3, 4) Again, diatoms prevailed in the phytoplankton community.

An increase of quantitative indices and the fluctuations in community structure (quantitative development of cyanobacteria) were observed in summer in the station 3 (Fig. 3, 4). Cyanophyta dominated in this site comprising approximately 84% of the total abundance and 65% of the total biomass mainly due to high numbers (156 000 cell/L) and biomass (0.46 g/m^3) of *Microcystis aeroginosa.*

The dominance of blue green algae was also recorded in the Arzni village station but the abundance become lower. The dominant species was *Aphanothece clathrata,* which comprised approximately 42% of the total abundance and 26% of the total biomass.

The values of the Shannon – Weaver index fluctuated from 1.63 to 2.92, saprobic index was within a range of 1.55 to 1.82 and reflected the oligo- to beta-mesosaprobic zones (Table 2).

High abundance of phytoplankton was observed in Hrazdan River during autumn and was associated with growth of the diatoms. The quantitative development of algae was registered at sites 1 and 3. The lowest abundance – 224 000 cell/L and biomass – 0.88 g/m^3 were recorded in the site 2 (Fig. 3, 4).

The dominating species in the phytoplankton community was *Cyclotella comta* which formed maximum abundance (372 000 cell/L) and biomass (0.82 g/m^3) at site 1.

Table 2. Values of Shannon biodiversity and saprobic indicies (*S*) in 2018.

	Spring		Summer		Autumn	
Sampling site	*S*	Shannon index	*S*	Shannon index	*S*	Shannon index
1	1.63	2.57	1.82	2.92	1.9	2.22
2	1.8	1.65	1.59	2.51	1.87	1.91
3	1.82	1.98	1.62	1.63	1.93	2.62
4	1.56	2.95	1.55	2.14	1.56	2.9

Among blue-green algae *Aphanothece clathrata* prevailed – 61% of the total abundance and 39% of the total biomass. Quantitative development of *Oscillatoria chlorina* was registered at the site 1 – 56 000 cell/L and 0.084 g/m^3. This species is known to be a polisaprobic species indicating organic pollution (Barinova et al., 2006).

Qualitative development of green algae from the genera *Characium* A. Br. (four species) and *Ankistrodesmus* Corda (two species) was noted in the river in autumn.

Along with high frequency species (*Trachelomonas volvocina* and *T. hispida*). *Euglena viridis* species was also registered among Euglenophyta.

Yellow-green algae were represented by *Tribonema monochloron* Pascher et Geitler in Pascher (1925) and were the most abundant at site 3 – 20 000 cell/L and 0.03 g/m^3.

The Shannon – Weaver diversity index varied from 1.6 to 2.9. Saprobic index varied from 1.6 to 1.93 and reflected the beta-mesosaprobic zones (Table 2).

Conclusions

High abundance and biodiversity of algae was revealed during investigations carried out in 2018 in the middle course of Hrazdan River. Big cell and colonial species of phytoplankton were registered. Diatoms were the principal component of algal abundance in the river. Cyanophyta were the subdominant group.

An increase in total algal count and diversity with intense development of species of the genera *Stephanodiscus*, *Melosira* and *Cyclotella* during summer and autumn was observed at site 1. This type of phytoplankton dynamics was observed previously in the Akhpara reservoir (Stepanyan and Hambaryan, 2016b) which might indicate the impact of the reservoir on the river.

Decrease of algae abundance was recorded at site 2 during the whole period of studies. A fluctuation in algae structure which includes the development of blue-green algae was registered towards downstream along the course of the river. *Aphanothece clathrata* and *Microcystis aeruginosa* species demonstrated the highest frequency of occurrence and mass development of these species in summer at sites 3 and 4 was recorded.

The level of organic pollution in Hrazdan River in 2018 was mainly beta-mesosaprobic according to saprobity index. The classification based on the Shannon – Weaver index indicates the status of the river as moderately polluted.

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