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INVESTIGATIONS OF FORMATION PHYTOPLANKTON COMMUNITY IN THE ARPA RIVER (ARMENIA) AND ITS MAIN TRIBUTARIES

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A modern study of the Arpa River and its tributaries allows evaluating the ecological state of the ecosystem according to phytoplankton development indicators and comparing it with previous data. It is known that modified control of hydrosystems for hydropower stations changes quantitative and qualitative indicators of water, which increases anthropogenic impact on the diversity of hydrobionts. In order to mitigate the environmental risks and improve the ecosystem self-cleaning it is necessary to carry out continuous monitoring and rapid assessment of the change in the composition of microalgae indicators.

***Keywords*:** phytoplankton, cyanobacteria, saprobity level, index of biodiversiti.

Introduction. The Arpa River is one of the largest tributaries of the trans-boundary Araks River. Its length is 128 *km*. 92 *km* of the river flows through the territory of Armenia. The catchment area is 2080 km^2. After the Ketchut reservoir along the Arpa–Sevan tunnel, about 94 million m^3/year of water (according to June 2018 data) is discharged to maintain the lake's water balance [1]. On the Arpa River and its main tributaries, viz. the Yehegis and Her-Her Rivers, about 15 small hydropower plants were built. The population in the catchment area is traditionally engaged in agriculture activity such as gardening, crop production and fish farming. In recent period, in river area, vine-making and tourism have been actively developing, which also leads to an increase in the load on the river ecosystem.

The aim of the research was to study phytoplankton of the Arpa River and its tributaries, in terms of pollution and technological transformations that are known to affect the diversity of aquatic biocenoses. Biodiversity of phytoplankton in the Arpa River catchment basin can serve as an integral bioindicator for water quality in the conditions of anthropogenic pressing [2, 3].

Material and Methods. Phytoplankton samplings (totally 40 samples) were done in 13 monitoring points (MP, see Tab. 1), in May, July, August 2016 and August 2017.

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Table 1

Coordinates and location of the investigated river sites in the Arpa River catchment basin

MP	North latitude	Eastern longitude	Location of MP
1	39°52'17.4"	45°42'54.9"	the Arpa River, the river part above the “Jermuk HPP-2” SHPP
2	39°52'06.4"	45°42'38.9"	the Arpa River, part of the river for the water intake of the “Jermuk HPP-2” HPP
3	39°41'33.0"	45°27'06.6"	the Arpa River, the river part above the “Arpa” SHPP
4	39°42'54.4"	45°24'53.5"	the Arpa River, part of the river for the water intake of the “Arpa” SHPP
5	39°43'55.8"	45°12'02.8"	the Arpa River, the river part above the “Areni” SHPP
6	39°43'49.4"	45°11'50.3"	the Arpa River, part of the river for the water intake of the “Areni” SHPP
7	39°43'31.9"	45°11'22.6"	the Arpa River, the river part after “Areni" SHPP water draining
8	39°48'50.6"	45°32'08.6"	the Her-Her River, the river part above the “Her-Her 1” SHPP
9	39°47'41.0"	45°32'20.0"	the Her-Her River, part of the river for the water intake of the “Her-Her 1” SHPP
10	39°47'37.7"	45°32'23.1"	the Her-Her River, the river part after “Her-Her 1” SHPP water draining
11	39°54'09.1"	45°29'41.9"	along the riverbed of the Yeghegis River, the part above the first SHPP
12	39°47'34.0"	45°18'19.5"	along the riverbed of the Yeghegis River, the last part for the water intake of SHPP
13	39°46'12.4"	45°18'31.0"	along the riverbed of the Yeghegis River the last part for the water draining of SHPP

A 1-liter water sample taken from each site was preserved with 40% formaldehyde solution and stored in a dark place. The fixed phytoplankton samples were settled in a dark space for 10–12 days, and then the volume was decreased from 1000 *mL* to 100 *mL*. Repeating the same process the volume of the experimental samples was reduced to 10 *mL* [4]. Taxonomic groups of phytoplankton were identified by using the keys/determinants of freshwater systems [5–9]. The diversity status of phytoplankton community in the river ecosystem was assessed by Shannon–Wiener diversity index [10]. Saprobity index of algae was calculated [11].

Results and Discussion. The study of the ecosystem of the Arpa River and its main tributaries, viz. the Her-Her and Eghegis Rivers, in different seasons of 2016–2017 revealed that the formation of phytoplankton in different parts of the river and in the main tributaries was sundry. Mass species belonged to the departments: Bacillariophyta (Diatoms) (47), Cyanophyta (17), Chlorophyta (15), Euglenophyta (4) and Xantophyta (1). The dominant group of phytoplankton of the Arpa River and its main tributaries in terms of their quantitative and qualitative indices were diatoms (57 and 60% of the total number and biomass) (Fig. 1).

The prevalence of diatom algae in general is inherent in the rivers of Armenia [12–14]. About 47 species are registered in the diatom group. The most diverse were the genera Navicula (7), Nitzschia (5), Pinnularia (4), Diatoma (3). High rates were achieved in the species *Rhoicosphenia curvata, Ceratoneis arcus, Fragilaria crotonensis, Cocconeis placentula, Diatoma vulgare, Cymbella ventricosa, Melosira granulata*. It is known that diatoms are cryobionts and can develop at low water temperatures in the spring and autumn seasons. Calculation data of thermovalency demonstrate the groups of cryobionts formed the stenothermal species of Bacillariophyta. This coincides with a common characteristic of diatoms as inhabitants of cold and clean water bodies. However, individual species such as *Melosira granulata* (*Ehrenberg.*) *Ralf. var granulate* is a mesophilic species (temperature indifferent). Also interesting is that large-celled *Pinnularia major* and *P. viridis* are not included in the group of thermoindicators, because they may be recorded all year round, which allows us to conclude that the species of the genus Pinnularia are eurythermal [15]. The sub-dominants were blue-green algae, constituting 29 and 27%, of the total number and biomass of the community, respectively. On all sections of the Arpa River and its tributaries there were species of *Microcystis aeruginosa, M. wessenbergii, Aphanothece clathrata* and *A. stagnina*, which are distributed in diverse aquatic ecosystems of Armenia and are background species of Cyanophyta [13, 16, 17].

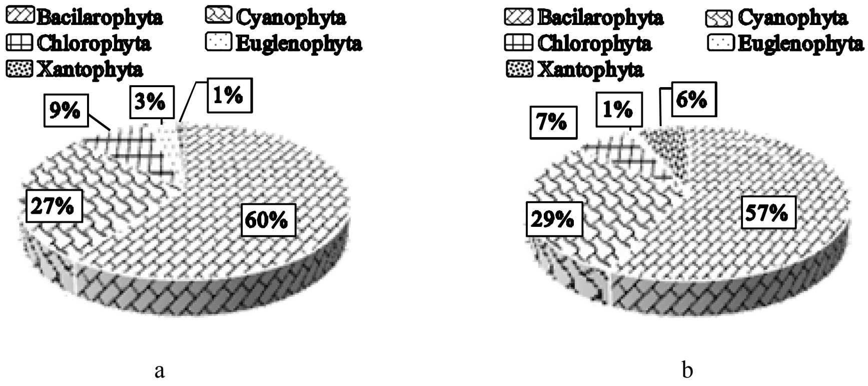

Fig. 1. Percentage of major groups of phytoplankton in the Arpa River and its tributaries by quantity (a) and biomass (b) in 2016–2017.

More than 20 species identified from cyanobacteria, which are indicators of pollution. Variety was observed in the genera Spirulina (4) and Oscillatoria (5). At separate observation points, *Pleurocapsa minor, Aphanizomenon f-a, Anabaena spiroides, Coelosphaerium kuetzingianum* were identified. The maximum of blue-green algae was observed in the Her-Her River at point No. 10, where species *Spirulina abbreviata, Oscillatoria lacustris, O. limnetica, Merismopedia elegans, Phormidium foveolarum* were recorded. Cyanobacteria species can quickly adapt to environmental changes, for example, *Oscillatoria sp.* and *Merismopedia sp.*, can adapt to the deterioration of light conditions in the reservoir [18]. In eutrophic reservoirs, Euglenophyta can replace the dominance of cyanobacteria, which is an indicator of organic contamination [19]. The percentage of green was 7 and 9% of the community, high values were in *Closterium pronum, Scenedesmus longispina, Pediastrum duplex, Dictiosphaerium pulchellum* and others. The numbers and biomass of the phytoplankton of the Arpa River and its tributaries for all algal groups are given in Tab. 2.

High rates of algae (844000 cells/L and 5.5 g/m^3) were registered in August 2017, the lowest (180923 cells/L and 1.03 g/m^3) were in May 2016. The areas of the Arpa and Yeghegis Rivers differed greatly. The quantitative development of phytoplankton in different parts of the Arpa River and its main tributaries had the dynamics given in Fig. 2.

Table 2

Biomass and density of phytoplankton in the Arpa River and its main tributares in 2016–2017

Phylum	Average biomass, g/m^3	Average density, cell/L
Bacillariophyta	2.29	335058
Cyanophyta	1.02	172492
Chlorophyta	0.33	38382
Euglenophyta	0.11	8533
Xantophyta	0.05	32000

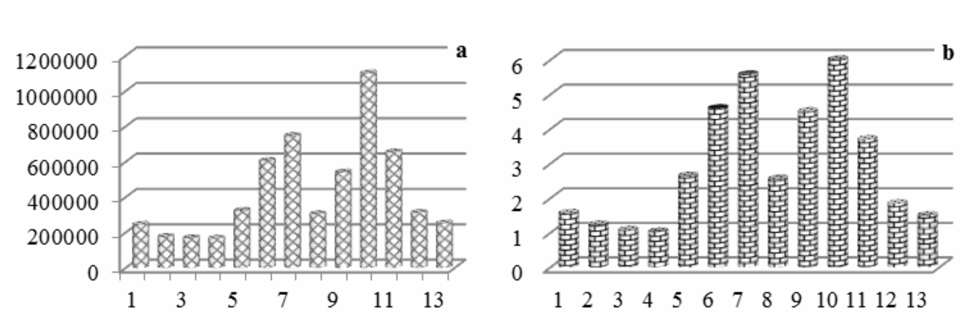

Fig. 2. Dynamics of quantity (a) and biomass (b) of the phytoplankton of the Arpa River and its tributaries.

High algal parameters were recorded at sampling point No. 10, however, the maximum in terms of biomass was recorded at sampling point No. 13, which is explained by the dominance of the large-cell blue-green species Phormidium foveolarum (372000 cells/L, biomass 7.04 g/m^3). There are 35 species found in the Arpa River. The diatoms of *Ceratonis arcus, Fragilara crotonensis, Pinnularia jibba* and species of the genera Diatoma (*Diatoma elongatum, D. hiemale, D. vulgare*) and Navicula (*Navicula cryphtocephala* and *N. radiosa*) were dominant. The average indices of diatoms were 359466 cells/L and 2.5 g/m^3, however, at the sampling point No. 5, the quantitative indices of blue-green algae had increased. In summer large-celled *Spirulina abbreviata* and *Phormidium foveolarum* (202555 cells/L and 1.4 g/m^3) developed. In the Arpa River, unlike the tributaries, green taxa *Closterium pronum, C. monilifer, C. dissipata, Botryococcus braunii, Oocystis solitaria, Treuboxia humicola* and *Ceratium hirundinella* developed. The migration of these species *Ceratium hirundinella* has been impacted by global warming. Therefore, species of Ceratium are used as biological indicators since the deeper they are found in the water column, the greater the impact from global warming [20]. The average values of green algae were 32098 cells/L and 0.2 g/m^3. The euglenic *Trachelomonas oblonga* taxon had an average of 6583 cells/L and 0.08 g/m^3, and the yellow-green species of *Tribonema monocloron* at point No. 6 (96000 cells/L

and 0.14 g/m^3) was recorded in the middle and lower reaches of the Arpa River. In general, in the phytoplankton of the Arpa River, 37% of the species were indicators of β-mesosaprobic conditions, which are characterized as an average contamination. About 32 mass species have been identified in the Her-Her River. The dominant species of Cyanophyta in the tributary Her-Her were *Phormidium foveolarum, Microcystis aeruginosa, Spirulina abbreviata, Oscillatoria lauterbornii, Merismopedia elegans* (648000 cells/*L* and 4 g/m^3) mass species. The maximum values were at point No. 10 (1100000 cells/*L* and 6 g/m^3), which is most likely explained by changes in water parameters after the technical use of the hydro-electric power station, decrease in its volume and increase in the water temperature. From diatoms, mass development reached the species *Cymbella helvetica, Rhoicosphenia curvata, Cocconeis placentula, Ceratoneis arcus*, as well as species of genera Navicula (351333 cells/*L* and 2.4 g/m^3). In the green group, *Chlorella vulgaris, Botryococcus braunii, Tetraedron trigonum*, from euglene *Trachelomonas volvocina* and *Euglena viridis* are recorded. The indicators of green were 52000 cells/*L* and 0.6 g/m^3, and the euglenes were 9333 cells/*L* and 0.13 g/m^3.

26 taxa have been registered in the River Yeghegis. As can be seen in Fig. 2, the largest quantitative indicators were observed at point No. 13, where blue-green species *Oscillatoria putrida, O. splendida* and *Phormidium foveolarum* dominated (283125 cells/*L* and 2 g/m^3). The maximum values of 547875 cells/*L* and 5 g/m^3 were the result of development of diatom species *Melosira granulata, Cymbella helvetica, C. ventricosa, Diatoma hiemale, Ceratoneis arcus*, and species of genera Navicula (261833 cells/*L* and 1.8 g/m^3). Species *Botryococcus braunii, Oocystis solitaria, Scenedesmus bijugatus* formed a dominant complex of green (3733 cells/*L* and 0.3 g/m^3). Species *Trachelomonas oblonga* (Euglenophyta) and *Tribonema monocloron* (Xantophyta) were found in the plankton of the Yeghegis River sporadically.

For the three rivers, despite the differences in development, there were common features, for example, Diatoms were most diverse in all rivers (by number of species). Species of the genus Navicula can be considered as background for the Arpa River and its tributaries. Since the main phytoplankton indicators have changed at the sampling points below the HPP, it can be assumed that this is due to changes in the water quantitative and qualitative parameters. Operation of small hydropower plants leads to non-compliance with environmental flows, partial draining of riverbed water in summer, overlapping migration routes for fish spawning and disruption of biodiversity indicators. There are many data on the impact of the operation of hydroelectric power stations mainly on fish and benthic communities, but phytoplankton is very sensitive to fluctuations in hydrological parameters and may also undergo significant changes due to the work of SHP [21, 22]. From this point of view, the results obtained are very important and valuable. In general, the main reason for the growth of phytoplankton was the reduced speed and volume of water in rivers. According to the Center of Armecomonitoring, water in the Arpa River and its tributaries during the period of research corresponded to class 2–4, from good and medium to insufficiently pure quality. The main contaminants are particulate matter and increased concentrations of NH^{4+}, NO^{3-}, NO^{2-} ions. The water temperature was from 3.7 to 18.7°*C*, and the pH value was from 6.7 to 8.2, the flow velocity was from 0.05–1.9 *m/s*. The Shannon–Wiener index and the index of saprobity for the phytoplankton of the Arpa River and tributaries are given in Fig. 3.

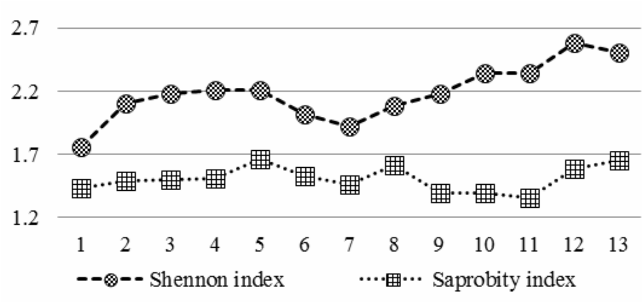

Fig. 3. Changes in the Shannon index and index of saprobity of phytoplankton of the Arpa River and its tributaries in 2016–2017.

The Shannon index was within 1.8–2.6, saprobity from 1.4–1.7, which indicates the average pollution of the Arpa River and its tributaries and the formation of an unstable community. In the Yeghegis tributary, the diversity indicators increase slightly, which is associated with an increase in the quantitative indices of phytoplankton with a decrease in saprobity indicators (Fig. 3). In 2013, 56 species of algae were identified in the Arpa River including 48 species (86%), bioindicators of organic water pollution, of which the β-mesosaprobic species were 44.6% and the o-β-mesosaprobic species accounted for 20% [23]. In 2016–2017 years, 84 species were identified, 81 of which (96%) were bioindicators of water pollution of various degrees, β-mesosaprobic species accounted for 16%, P-polysaprobic species accounted for 11%. Analysis of the comparative data indicates a tendency for a gradual increase in the average level of organic water pollution.

Conclusion. The spatial heterogeneity in the development of the phytoplankton of the Arpa River and the tributaries has been revealed at different sites and in different seasons, which indicates a different level of anthropogenic impact. The quantitative and qualitative parameters of phytoplankton in the observation sites revealed an increase of indicators values at the observation points located, in general, downstream of the HPP. The decrease in the water velocity and its quantity after the hydroelectric power station was the main factor for the growth of phytoplankton. The spread and increase of quantitative indices of cyanobacteria in phytoplankton is the main change detected during the research period, which indicates risks for both functioning of the ecosystem and human health.

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