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COMPARATIVE ANALYSIS OF THE *Ciliophora* FAUNA IN FRESHWATER BODIES OF THE NAKHCHIVAN AUTONOMOUS REPUBLIC

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СРАВНИТЕЛЬНЫЙ АНАЛИЗ ФАУНЫ *Ciliophora* В ПРЕСНОВОДНЫХ ВОДОЕМАХ НАХЧЫВАНСКОЙ АВТОНОМНОЙ РЕСПУБЛИКИ

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Abstract. Free-living ciliates are a group of microscopic organisms that play an important role in the trophic structure of aquatic ecosystems. They participate in the cycling of substances by feeding on bacteria, detritus, and other small microorganisms, and they are also used as bioindicators in assessing the ecological state of water bodies. The species composition, abundance, and distribution of ciliates across biotopes are closely related to the physicochemical properties of water, the amount of organic matter, the nature of the substrate, the oxygen regime, temperature, and trophic level. The comparative characteristics of the free-living ciliate fauna across various aquatic biotopes—plankton, benthos, the littoral zone, areas rich in vegetation, and substrates rich in organic matter—are considered. The changes in species richness and dominant forms in different biotopes, the formation of ecological groups, and the bioindicator significance of ciliates are analyzed.

Аннотация. Свободноживущие инфузории (*Ciliophora*) – группа микроскопических организмов, играющих важную роль в трофической структуре водных экосистем. Они участвуют в круговороте веществ, питаясь бактериями, детритом и другими мелкими микроорганизмами, а также используются в качестве биоиндикаторов при оценке экологического состояния водоемов. Видовой состав, численность и распространение инфузорий по биотопам тесно связаны с физико-химическими свойствами воды, количеством органического вещества, природой субстрата, кислородным режимом, температурой и трофическим уровнем. Рассмотрены сравнительные характеристики фауны свободноживущих инфузорий в различных водных биотопах — планктоне, бентосе, литоральной зоне, районах, богатых растительностью, и субстратах, богатых органическим веществом. Проанализированы изменения видового богатства и доминирующих форм в различных биотопах, формирование экологических групп и биоиндикаторное значение инфузорий.

Keywords: Ciliophora, fauna, biotope, plankton, benthos, species diversity, bioindicator, aquatic ecosystem.

Ключевые слова: Ciliophora, фауна, биотоп, планктон, бентос, видовое разнообразие, биоиндикатор, водная экосистема.

Ciliates (*Ciliophora*) form a very diverse group from a morphological and ecological point of view. Their representatives can settle in the water column, in bottom sediments, on aquatic plants, on silt and sandy substrates, as well as in microhabitats rich in organic matter. The preference of

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individual species for certain biotopes is related to their ecological valence and attitude to environmental factors. Comparison of Ciliates fauna by biotope is important not only in terms of determining species diversity, but also in terms of assessing the ecological state of the water body. Thus, while some species have a wide ecological range, others are more sensitive to certain temperature, oxygen, pH, organic matter and substrate conditions. The main goal of the study is to comparatively assess the distribution of free-living ciliates n fauna in different biotopes, identify ecological factors affecting changes in species composition and abundance, and investigate the bioindicator significance of individual ciliates n groups [1, 2].

Materials and methods

When comparing free-living ciliates across biotopes, it is advisable to take samples from different ecological parts of the water body. Taking samples in different seasons - spring, summer, autumn and winter - allows you to determine the seasonal dynamics of the fauna.

Plankton samples can be taken from different depths of the water column, and benthic samples from the bottom sediment layer. When studying ciliates (Phylum Ciliophora) associated with aquatic plants, the stem, leaves and root parts of the plant can be studied separately [7].

Results and their discussion

Seasonal quantitative changes in ciliates communities living in the reservoirs of the autonomous republic are explained by the sequential succession processes that occur seasonally in the species diversity of biotopes in these and other water bodies. In other words, changes in ecological conditions change the composition and quantity of ciliates communities every year.

As a result of the conducted studies, six main biotopes were identified in the reservoirs. Of these, benthic sand and silty-sand biotopes are relatively rare and limited in terms of area. Although the abiotic factors (substrate structure, oxygen regime, organic matter content, etc.) in these biotopes are close to each other, the composition of free-living ciliates species living here differs significantly.

During the studies, a total of 58 species of ciliates were recorded in sand biotopes and 80 species in silty-sand biotopes. Comparative analysis showed that the level of similarity of the total species diversity recorded in both biotopes is 48%. This result shows that, despite the similarity of ecological conditions between biotopes, the species composition and structure of the ciliates n communities formed there reflect different ecological adaptations [3-6].

Species such as *Limnostrombidium viride* and various ciliates n genera such as *Chlamydodon, Coleps* are widespread in sand biotopes. These species form the species diversity of free-living ciliates n communities of the sand biotope community. Ciliates n genera such as *Loxodes, Blepharisma* and various eurybiont bacteriophages (mainly *Cyclidium* and *Uronema*) are added to the sand biotope species.

According to the marine biologists of the autonomous republic, the Gray silt benthic biotope has 72 species. The community is mainly composed of species of the genera *Loxodes, Blepharisma* and *Condylostoma*. In addition, species of the genus *Halteria*, which are mainly found in planktonic ciliates communities, along with *Limnostrombidium viride* and *Didinium nasutum*, were also found in the bottom layers. Eurybiont bacteriophages such as *Cyclidium* and *Uronema* were also noted.

A comparative analysis of the total species diversity of free-living ciliates of gray mud and silty sand communities showed that the total species diversity was quite high, equal to 50%. At the same time, the highest species diversity was observed in the free-living ciliates communities of the Gray silt benthic biotope and silty sand rich in plant residues (57%).

Free-living ciliates communities in the studied biotopes were characterized by high taxonomic diversity. Although these communities are dominated by representatives of the genera *Blepharisma,*

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Spirostomum, Histriculus, Urostyla, Euplotes, Paramecium and *Ophryoglena*, numerous other ciliates genera representing various ecological groups have also been recorded.

Among the benthic biotopes of aquatic plants, sandy areas usually lag behind other biotopes in terms of species diversity and population density. However, the black-mud biotope is characterized by its unique ecological conditions and is characterized as a specific biological environment inhabited by numerous specialized ciliates n species that are resistant to hydrogen sulfide and adapted to low oxygen concentrations. The black-mud biotope lagged behind other benthic biotopes in terms of species richness, being represented by only 66 ciliates species. However, the ciliates fauna of this biotope demonstrated high specificity and showed significant similarity with other muddy benthic biotopes. Thus, more than half of the species found in the black-mud biotope were also recorded in other muddy biotopes, this indicator was 52% in gray mud, 55% in muddy-sandy biotope, and 50% in silt rich in plant residues. This indicates that the ciliates fauna has common ecological characteristics among different muddy biotopes. Comparing the species diversity of all muddy benthic soils, it is possible to identify free-living ciliates species common to the species distribution of muddy biotopes. These include *Colpidium, Loxodes, Spirostomum, Plagiopyla* and other species. Most of the ciliates found are highly active bacteriophages in ciliates communities living mainly in muddy biotopes. Again, the genera indicated as sapropelebionts are ciliates communities of the black-mud benthic biotope formed by *Metopus, Caenomorpha, Epalxella, Saprodinium.* Each of the above-mentioned ciliates , together with a small amount of oxygen found in water and hydrogen sulfide found in water, has the ability to render the population harmless. Free-living ciliates communities of plankton of the reservoirs consist of 46 species. These include the typical plankton genera of oligotrichs, *Halteria* and *Limnostrombidium.* We observed the presence of other oligotrichs in the benthic plankton in the upper part of the reservoirs of aquatic plants and silty soil. In general, the diversity of plankton in the reservoirs of the autonomous republic is in close contact with the biotopes of phytophilous ciliates and periphyton.

Comparative analysis of the species diversity of silty benthic soils allows us to identify the species of free-living ciliates that are typical for these biotopes and are widespread. These include *Colpidium, Loxodes, Spirostomum, Plagiopyla* and other species. Most of the mentioned ciliates are highly active bacteriophages in ciliates communities living mainly in silty biotopes. Ciliates communities of the black-silt benthic biotope are dominated by representatives of the genera *Metopus, Caenomorpha, Epalxella, Saprodinium* which belong mainly to the sapropelbiont ecological group. Species belonging to these genera are characterized by high adaptability to oxygen deficiency and hydrogen sulfide-rich environmental conditions. Their wide distribution in black-silt biotopes indicates that these species are able to survive in anaerobic or microaerophilic conditions. The results of our pairwise comparison of the total species diversity of free-living ciliates communities of plankton and benthic biotopes showed minimal inequality between these two biotopes. For example, in the muddy ciliates n communities, which were rich in plankton and plant debris, the species diversity of ciliates n communities was the lowest (14%). The similarity of planktonic ciliates n communities with muddy sand and sand biotopes was 17% and 25%, and with free-living ciliates n communities — 23% and 25%. (Table).

Thus, the similarity between the species diversity of ciliates n communities of planktonic biotopes and benthic biotopes was very low and ranged from 14% (silt rich in plant debris) to 25% (black silt). A pairwise comparison between the species diversity of ciliates n communities of planktonic biotopes and periphyton and phytophilous ciliates biotopes showed a total species diversity of 37% and 59%. It was much higher when compared in benthic biotopes. Along with pairwise comparisons of the similarity of species diversity of ciliates communities in each of the

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studied biotopes of aquatic plants, Bray-Curtis cluster analysis was used to determine the degree of similarity of species diversity of ciliates in all identified communities.

Table

SPECIES DIVERSITY OF FREE-LIVING INFUSORIA IN DIFFERENT BIOTOPES OF THE AUTONOMOUS REPUBLIC'S LAKES (according to Chekanoski-Serensen in %)

Biotoplar	*Sand*	*Silty sand*	*Grey silt*	*Silt*	*Black silt*	*Plankton*	*Periphyton*	*Phytocenosis*
Sand	-	46	38	44	30	28	42	36
Silty sand	46	-	53	49	57	20	31	37
Grey silt	38	53	-	61	48	26	35	39
Silt rich in plant residues	44	49	61	-	54	18	27	34
Black silt	30	57	48	54	-	29	33	28
Plankton	28	20	26	18	29	-	41	56
Periphyton	42	31	35	27	33	41	-	52
Phytocenosis	36	37	39	34	28	56	52	-

As shown in Figure 1, the cluster that brings together free-living ciliates communities of the benthic biotope and black-mud ciliates communities is the one with the highest species diversity. As it was determined, these are explained by the specific ecological conditions of the benthic biotope. The next cluster combines biotopes with a relatively low degree of similarity in terms of species diversity of free-living ciliates communities - environments related to plankton, periphyton and phytociliates. The species composition and distribution indicators observed in this cluster reflect the diversity of hydrobiological conditions and ecological factors (Figure).

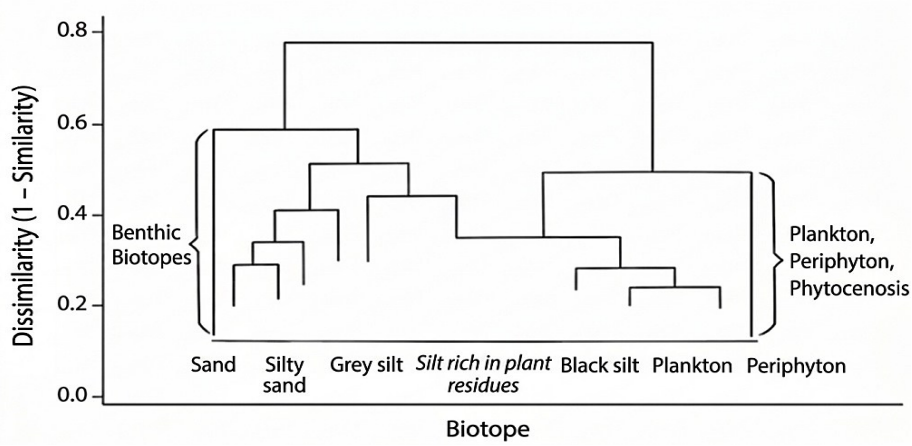


Figure. Similarity index of species diversity of free-living ciliates n communities to those found in the studied biotopes, based on Bray-Curtis cluster analysis

Thus, the data obtained as a result of the conducted analyses show that, despite the specific ecological characteristics existing among the studied biotopes, the highest level of similarity is observed between the species diversity of free-living ciliates n communities formed in benthic biotopes. In terms of species diversity, the second place in terms of similarity between communities is occupied by free-living ciliates n communities formed in plankton, periphyton and phytophilous ciliates biotopes. This result can be explained by the relative stability of environmental conditions and trophic relationships in these biotopes.

Since the diversity of free-living ciliates n communities is somewhat smaller, it includes the biotopes of plankton, periphyton and phytociliate. Thus, the results of the study showed that there is the highest level of similarity between the species diversity of free-living ciliates n communities of

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benthic biotopes. Periphytons and phytophilous ciliates are the second largest plankton group in terms of species diversity.

Our long-term observations have shown that the core of plankton ciliates communities is formed by representatives of typical plankton genera such as *Pelagohalteria, Monodinium, Didinium, Askenasia, Mesodinium*, as well as *Linostomatella vorticella*, which is characteristic of fresh and slightly saline water bodies. However, as already mentioned above, the plankton communities of ciliates of Lake Nehram, which are shallow and rich in aquatic plants, are often enriched with numerous facultative species. In particular, during windy weather, as a result of mixing of the water mass, the number of representatives of the *Paramecium* genera increases, which leads to their temporary dominance in plankton.

At the same time, eurybiont representatives of the *Cylidium* and *Uronema* genera found in almost all studied biotopes, as well as *Zoothamnium* and other peritrix ciliates species that break away from the substrate and enter the water column, are included in the plankton community. This reflects the high dynamics of plankton biotopes and their ecological connections with other biotopes.

Periphyton ciliates communities have specific ecological features inherent only to this biotope. In particular, the presence of representatives of the genera *Chlamydodon* characterizes the composition of typical ciliates that reproduce in water. Also, these ciliates , together with representatives of the genera *Epistylis, Vorticella, Carchesium* and *Zoothamnium*, inhabit the primary ciliates communities of the periphyton.

Unlike plankton and phytociliate ciliates communities, periphyton ciliates communities inhabit not only plant surfaces, but also hard substrates of animal origin covered with Biofouling. As a result of this feature, slowly crawling phytophages and various types of peritrichs that adhere to the substrate predominate in periphyton communities. Calculation of the similarity ind ex of periphyton and planktonic ciliates n communities showed that the similarity between the species composition of these communities is 37%, while the similarity between plankton and phytocilliocenosis communities is slightly higher, amounting to 59%. Although only 46 species were recorded in planktonic communities and 80 species in phytocilliocenosis communities, there are numerous common species in both communities. Thus, among the species common to both communities are representatives of the genera *Limnostrombidium, Monodinium, Didinium, Askenasia, Mesodinium* and others.

Our studies have shown that the degree of similarity of the species diversity of free-living ciliates n communities formed in periphyton and phytocilliocenosis biotopes is 49%. The number of common ciliates n species for these biotopes is relatively small. These common species mainly consist of representatives of the genera *Cyclidium, Uronema, Vorticella* and other similar genera. Such ciliates settle both on polluted surfaces and among the thalli of algae and higher aquatic plants.

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