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Seasonal changes of free-living ciliate communities in different biotopes of the Agzibir Lake

I.F. Mansimova, I.Kh. Alakbarov

The Agzibir Lake is optimal in terms of hydrochemical and hydrobiological factors for formation of higher biodiversity of free-living ciliates. This is facilitated with continuous entering biogenic elements as a result of metabolism of large bird colonies and decaying organic residues of plant and animal origin. The Agzybir Lake having a link with the Caspian Sea in spring and fall is a place of spawning and the subsequent development of larvae of many commercially valuable fishes of the Caspian Sea, for which ciliates are a valuable starting food source in early stages of ontogenesis. During 2014–2019, totally 169 species of free-living ciliates were found by us, and 34 of them were observed for the first time for the Caspian fauna. The minimum species diversity was observed in plankton, where 46 species were recorded. In benthos of the sandy biotope, 58 species were found, whereas in the silty sand one, 80 species. At the silt soil in the biotope of gray silt, we found 72 species, the maximum species diversity (84 species) was observed in the silt biotope with plant residues, while at the black silt with sapropel communities 66 species of free-living ciliates were found. In the periphyton biotope, we observed 71 species, while in coastal thickets of algae (phytociliocenosis) 79 species of free-living ciliates were found. As with the sandy biotope, the black silt biotope, sometimes with small communities of sapropel silt, is much smaller in area than the rest of benthic biotopes of the Agzibir Lake. Yet, free-living ciliate communities of black silt are specific and include several species that are tolerant to low oxygen and hydrogen sulfide in water. The seasonal variations of total quantity of free-living ciliates of benthic biotopes have three maxima (in spring, summer and autumn). As for the rest of biotopes of plankton, periphyton and phytociliocenosis, only two maxima (in spring and autumn) were revealed. The greatest similarity of species diversity was observed within benthic communities. But lowest similarity was observed between sapropel silt and the rest. As was already mentioned, this is due to specific ecological conditions of sapropel silt biotope.

Key words: *Agzibir Lake, Azerbaijan, plankton, benthos, periphyton, biotope, ciliates, seasonal changes.*

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Introduction

The Agzibir Lake is located in 120 km to the north of Baku, on the western coast of the Middle Caspian (46°16′ – 41°19′ N, 49°03′ – 49°07′ E). It is quite large (area 3600 ha) and shallow; the greatest depth is 3 m, salinity is 3.5 ‰ (brackish), pH is 7.2–8.3, i.e. weakly alkaline (Abdullayev et al., 2014).

Currently, the Agzibir Lake is fed by atmospheric precipitation, groundwater and the waters of three rivers – the Shabranchay, the Devechichay and the Takhtakorpuchay. Accordingly, the maximum water level in the Agzibir is observed in spring, with the increase in the flow of river waters. Due to a canal connecting it with the sea, this water body has a connection with the Caspian Sea in spring. The biological and practical importance of the Agzibir Lake is great, since it and the canal connecting it with the sea include valuable commercial fish spawning sites (Kasimov, 1972) and this habitat provides proper conditions for further development of fish and their growth from the larval stage to the adult.

It is known that free-living ciliates periodically developing to very high values of the quantity and biomass are of great importance for production and destruction processes of organic matter in water bodies (Alekperov, 2012; Alekperov, Mansimova, 2017). Being bacteriophages and algophages, on the one hand, free-living ciliates are active participants in the bio-purification process in the water body, and on the other hand, in case of their mass development with optimum temperature and abundance of food organisms, free-living ciliates themselves are food objects for small size groups of multicellular organisms (Rotifera and Copepoda), as well as larvae of many fishes during the early stages of their ontogenesis (Witzani, Nowacki, 2016).

Based on the above mentioned, the study of species diversity and numbers of the free-living ciliates of the Agzibir Lake was carried out for all the seasons of the year.

Material and methods

Sampling was carried out in various parts of the Agzibir Lake in 2014–2019 (Fig. 1). Totally, 120 samples of plankton, benthos and coastal aquatic plants were collected for the determination of ciliate

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species diversity. In addition, 115 samples were collected, which were delivered and processed in the laboratory within the shortest possible time for the quantitative analysis. During the study, we also determined hydrochemical parameters of water at different points of sampling by a Horiba U-52 Multiparameter Meter, measuring a number of water parameters, including temperature, oxygen regime, pH etc.

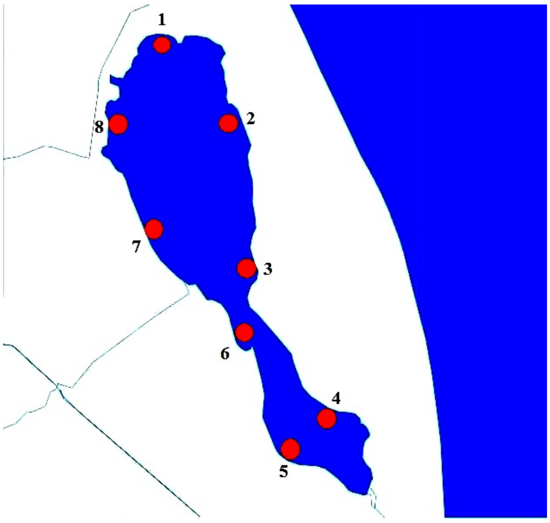

Fig. 1. Sampling points in different biotopes of the Agzibir Lake

A part of the samples was examined on the site, and the bulk of the collected material was processed in the Laboratory of Protozoology at the Institute of Zoology of the National Academy of Sciences of Azerbaijan. Ciliates were caught by microcapillaries, then studied *in vivo*. The impregnation methods of silver nitrate (Chatton, Lwoff, 1930) and protargol (Alekperov, 1992) were used for detailed taxonomic processing. The determination of species composition was carried out by comparing with our previous impregnated preparations and with a number of recent publications and classic monographs, the authors of which used these methods that are mandatory in modern research (Dragesco, Dragesco-Kerneis, 1986; Foissner et al., 1991; Alekperov, 2005).

Quantitative accounting was carried out by means of the modern cytometer "FlowCam" (USA) and in some cases by counting live ciliates in Bogorov's chamber in 5 ml of each sample, followed by recalculation into 1 liter of water or 1 dm^2 of the bottom surface.

The comparison of the species diversity community was carried out by the Bray-Curtis cluster analysis method and according to Chekanovsky-Sørensen (Sørensen, 1948). These analyzes were carried out using the "Biodiversity Professional v.2" computer program.

Results and discussion

Totally, 169 species of free-living ciliates were found during the investigation, of which 34 species were observed for the first time for the Caucasus fauna. Ciliates species composition and distribution are presented in Table 1.

As it is seen from the table, the ciliate species diversity of the Agzibir Lake is represented by 169 species belonging to 42 families. Thirty four species were observed for the first time for the Caucasus fauna.

The analysis of the obtained data showed that the greatest species richness was observed in benthos in gray silt (72 species) and in silt with plant residues (84 species). A bit lower species richness was observed among the thickets of aquatic plants (*Chara* sp.) denoted by the term "phytociliocenosis", where 79 species were observed. Eighty species were observed in the biotope of silty sand, 58 species in the sand, and the minimum species richness was observed in plankton (46 species) and periphyton (71 species).

Table 1.

Ciliates species composition and distribution in the biotopes of Agzibir Lake

	Species	Sampling points							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Phylum Ciliophora Doflein, 1901								
	Classis Kariorelictea Corliss, 1974								
	Fam. Loxodidae Butschli, 1889								
1.	*Loxodes striatus* (Engelmann, 1862)		+	+	+	+			
2.	*L. kahli* Dragesco et Njine, 1971*		+	+	+	+			
	Fam. Blepharismidae Jankowski in Small et Lynn, 1985								
3.	*Blepharisma steini* Kahl,1932	+	+	+	+				
4.	*B. tardum* Kahl, 1928		+	+					
5.	*B. undulans* Stein, 1868	+	+		+				
	Fam. Spirostomatidae Stein, 1867								
6.	*Spirostomum teres* Clap. et Lach., 1859	+	+	+	+	+			
7.	*S. loxodes* Stokes, 1885*	+		+	+	+			
	Fam. Condylostomatidae Kahl in Dofflein et Reichenov, 1927								
8.	*Condylostoma fieldi* Hartwig, 1973*		+	+	+				
9.	*C. granulosum* Bullington, 1940	+	+		+				
10.	*C. magnum* Spiegel, 1926				+				
11.	*C. arenarium* Siegel, 1926		+	+	+				
12.	*Linostomatella vorticella* (Ehrenberg, 1833)						+		+
	Fam. Amphisiellidae Jankowski, 1979								
13.	*A. quadrinucleata* Berger et Foissner, 1989		+	+	+	+			
14.	*A. vitiphila* (Foissner, 1987)		+		+	+			
15.	*A. marioni* Wicklow, 1982			+	+				
	Fam. Oxytrichidae Ehrenberg, 1838								
16.	*Stylonychia bifaria* (Stokes, 1887)			+	+	+			
17.	*S. vorax* Stokes, 1885		+	+	+				
18.	*S. putrina* Stokes, 1885	+				+	+	+	
19.	*S. quadrinucleata* Alekperov et Musaev, 1988		+	+		+			
20.	*Histriculus muscorum* Kahl, 1932		+	+	+	+			
	Fam. Keronidae Dujardin, 1841								
21.	*Keronopsis arenivorus* Dragesco, 1954	+	+		+				
22.	*K. gracilis* Dragesco, 1954	+	+	+	+				
	Fam. Urostylidae Bütschli, 1889								
23.	*Urostyla marina* Kahl, 1932		+	+	+				
24.	*U. grandis* Ehrenberg,1838	+	+			+			
25.	*Pseudoamphisiella alveolata* (Kahl, 1932)*		+	+	+				
26.	*Holosticha pullaster* (Müller, 1773)*	+	+	+	+				
27.	*H. foissneri* Petz et al., 1995	+	+			+			
	Fam. Kiitrichidae Nozawa, 1941								
28.	*Musajevella minima* Alekperov, 1984			+	+				+

Table 1, continuation

	Fam. Euplotidae Ehrenberg, 1838								
29.	*Euplotes pseudoraikovi* Alekperov, 2005	+	+	+	+	+	+		+
30.	*E. alatus* Kahl, 1932		+	+				+	
31.	*E. focardii* Valbonesi et Luporini, 1990*		+		+				+
	Fam. Aspidiscidae Ehrenberg, 1838								
32.	*Aspidisca turrita* (Ehrenberg, 1838)	+	+		+			+	
33.	*A. binucleata* Kahl, 1932			+				+	
34.	*A. steini* Buddendrock, 1920			+					+
	Fam. Halteriidae Claparede et Lachmann, 1858								
35.	*Halteria grandinella* (Müller, 1786)			+		+	+		+
36.	*H. maxima* Szabo, 1934*		+	+			+		
37.	*Pelagohalteria viridis* (Fromentel, 1876)						+		+
38.	*P. cirrifera* (Kahl, 1932)		+				+		+
	Fam. Strombidiidae F.-F.,1970								
39.	*Heterostrombidium calkinsi* Fauré-Fremiet, 1932*						+	+	+
40.	*H. fauréi* (Dragesco, 1960)			+			+		+
41.	*H. clavellinae* (Buddenbrock, 1922)*								+
42.	*Limnostrombidium viride* (Stein, 1867)	+	+	+	+	+	+	+	+
43.	*Novistrombidium testaceum* (A., 1914)						+	+	+
44.	*Spirostrombidium coronatum* (Sauerbrey, 1928)				+		+		+
45.	*Strombidium apsheronicum* Alekperov et Asadullayeva, 1997						+	+	+
46.	*S. oculatum* Gruber, 1888						+		
47.	*S. obliquum* Kahl, 1932						+	+	+
48.	*S. elatum* Alekperov,1985						+		+
	Fam. Metopidae Kahl, 1927								
49.	*Metopus acidiferus* Kahl, 1935*					+			
50.	*M. caucasicus* Alekperov, 1984		+	+	+	+			+
51.	*M. fuscoides* Alekperov, 1984				+	+			
52.	*M. major* Kahl, 1932				+				
53.	*M. turbo* Dragesco et Dr.-Kerneis,1986			+	+	+			
54.	*M. vestitus* Kahl, 1935*				+				
	Fam. Caenomorphida Poche, 1913								
55.	*Caenomorpha lata* (Kahl, 1927)				+	+			
56.	*C. medusula* Perty,1832		+	+		+			
	Fam. Epalxellidae Corliss, 1960								
57.	*Pelodinium rotundum* Kahl, 1926*		+	+	+	+			
58.	*Epalxella antiquorum* (Penard, 1922)				+	+			
59.	*E. triangula* (Kahl, 1932)*				+	+			
60.	*Saprodinium halophilum* Kahl, 1932				+	+			
61.	*S. dentatum* Lauterborn, 1901		+	+		+			
62.	*S. mimeticum* (Penard, 1922)*	+				+			
63.	*S. spinigerum* Kahl, 1932*		+		+	+			

Table 1, continuation

	Fam. Enchelyidae Ehrenberg, 1838								
64.	*Enchelys marina* (Meunier, 1910)						+		+
65.	*E. gasterosteus* Kahl, 1926							+	
	Fam. Lacrymariidae Fromentel, 1876								
66.	*Lacrymaria olor* (Müller, 1786)	+	+	+	+				+
67.	*L. marina* Kahl, 1933	+	+						
68.	*L. acuta* Kahl, 1933*				+		+	+	+
69.	*L. minuta* Dragesco, 1963	+		+					
70.	*L. bulbosa* Alekperov, 1984				+				
	Fam. Spathidiidae Kahl, 1929								
71.	*Spathidium moniliforme* Bhatia, 1920				+			+	+
72.	*Perispira ovum* Stein, 1859				+	+			
73.	*P. oligospira* Gelei, 1954			+		+		+	
	Fam. Didiniidae Poche, 1913								
74.	*Monodinium balbianii* Fabre-Dom., 1888						+		+
75.	*M. perrieri* Delphy, 1925						+	+	+
76.	*M. alveolatum* Kahl, 1930			+	+	+	+	+	+
77.	*M. chlorelligerum* Krainer, 1995						+		+
78.	*Didinium nasutum* (Müller, 1773)	+	+	+	+	+	+	+	+
	Fam. Trachelidae Ehrenberg, 1838								
79.	*Paraspathidium obliquum* Dragesco, 1963		+			+		+	+
80.	*P. fuscum* Kahl, 1928	+	+	+	+	+		+	
81.	*P. longinucleatum* Czapik et Jordan, 1976*	+	+			+			+
	Fam. Mesodiniidae Jankowski, 1980								
82.	*Askenasia mobilis* Alekperov, 1984						+		+
83.	*A. confunis* Alekperov, 1984						+		+
84.	*Mesodinium apsheronicum* Alekperov et Asadullayeva, 1996						+		+
85.	*M. cinctum* Kahl, 1930						+		+
	Fam. Amphileptidae Butschli, 1889								
86.	*Litonotus triqueter* Penard, 1922	+			+				
87.	*L. obtusus* Maupas, 1888*		+			+			
88.	*L. crystallinus* (Vuxanovici, 1960)*				+			+	
89.	*L. undulatum* Sauerbrey, 1928			+				+	
90.	*L. semilunare* Vuxanovichi, 1960*	+							+
91.	*L. hyalinum* Vacelet, 1961		+			+		+	
	Fam. Chlamydodontidae Stein, 1859								
92.	*Chlamydodon mnemosyne* Ehrenberg, 1835	+	+		+	+		+	+
93.	*C. obliquus* Kahl, 1931		+	+	+	+		+	
94.	*C. erythrorhynchus* (Perejaslawzewa, 1885)	+	+	+	+	+	+	+	+
95.	*C. major* (Kahl, 1931)			+	+			+	+
	Fam. Dysteriidae Claparede et Lach., 1858								
96.	*Dysteria procera* Kahl, 1931		+	+	+			+	+

Table 1, continuation

97.	*D. monostyla* (Ehrenberg, 1838)							+	
98.	*D. pectinate* (Nowlin, 1910)	+				+		+	+
	Fam. Orthodonellidae Jankowski, 1968								
99.	*Zosterodasys debilis* Alekperov, 1984	+			+			+	+
100.	*Z. cantabrica* Fern.-Leb. et Alekperov, 1995		+		+	+		+	+
	Fam. Microthoracidae Wrzesn. 1870								
101.	*Microthorax glaber* Kahl, 1926*	+	+	+		+			
102.	*M. transversus* Foissner, 1985		+		+				
103.	*M. tridentatus* Kahl, 1931*	+	+	+	+				
	Fam. Platyophryidae Puytorac, Perez-Paniagua et Perez-Silva, 1979								
104.	*Platyophrya vorax* Kahl, 1926	+	+						
105.	*P. spumacola* Kahl, 1927			+	+	+			+
106.	*P. sphagni* (Penard, 1922)*	+			+				+
	Fam. Colepidae Nitzsch, 1827								
107.	*Coleps trichotus* Savi, 1913	+	+	+	+	+	+	+	+
108.	*C. spiralis* Noland, 1937	+		+	+			+	+
109.	*C. arenicolus* Dragesco, 1965		+					+	
110.	*C. spinosus* Vacelet, 1961	+	+					+	+
111.	*C. elongatus* Ehrenberg, 1833	+	+				+		+
112.	*C. amphacanthus* Ehrenberg, 1833	+	+	+	+	+		+	+
	Fam. Holophryidae Perty, 1852								
113.	*Holophrya vorax* Dragesco, 1960		+	+	+	+		+	+
114.	*H. salinarum* Foissner, Agata et Berger, 2002						+	+	+
115.	**Fam. Placidae** Small et linn, 1985								
116.	*Placus longinucleatus* Song et Wilbert, 1989	+	+		+				
	Fam. Plagiopylidae Schew. 1896								
117.	*Sonderia macrochilus* Kahl, 1931*			+	+	+			
118.	*S. megalabiata* Alekperov et Asadullayeva, 1996			+	+	+			
119.	*S. paralabiata* Small et Lynn, 1985*			+	+				
120.	*S. sinuate* Kahl, 1931*				+				
121.	*Plagiopyla ovata* Kahl, 1930			+	+	+			
122.	*P. nasuta* Stein, 1860	+	+	+	+	+			
123.	**Fam**. **Frontoniidae** Kahl, 1926								
124.	*Frontonia leucas* Ehrenberg, 1838	+	+			+			
125.	*F. marina* Fabre-Domerque, 1891		+				+		+
126.	**Fam. Urotrichidae** Small et Lynn, 1985								
127.	*Urotricha atipica* Alekperov, 1993	+	+						
128.	*U. turanica* Alekperov, 1997	+			+		+	+	
129.	*U. macrostoma* Foissner, 1983					+		+	+
130.	*Longifragma gracilis* Alekperov et Musaev, 1988	+		+			+		
	Fam. Parameciidae Dujardin, 1840								
131.	*Paramecium caudatum* Ehrenberg, 1832	+	+	+	+	+	+	+	+

Table 1, continuation

132.	*P. multimicronucleatum* Pow. et Mitchell, 1910			+	+	+			+
	Fam. Lembadionidae Jankowski in Corliss, 1977								
134.	*Lembadion bullinum* (Muller, 1786)	+		+				+	
135.	*L. lucens* (Maskell, 1987)	+	+					+	+
	Fam. Turaniellidae Didier, 1971								
133.	*Colpidium colpoda* (Losana, 1829)		+	+	+	+			
	Fam. Glaucomidae Corliss, 1971								
134.	*Glaucoma scintillans* Ehrenberg, 1830		+	+	+	+		+	+
135.	*G. chattoni* Corliss, 1959		+		+				
	Fam. Ophryoglenidae Kent, 1881								
136.	*Ophryoglena atra* Ehrenberg, 1838	+	+	+	+	+	+	+	+
137.	*O. catenula* Savoie, 1965*		+	+	+	+			+
138.	*O. flava* (Ehrenberg, 1838)	+		+				+	
	Fam. Loxocephalidae Jankowski, 1964								
139.	*Dexiotricha simplex* Penard, 1922		+	+	+	+			+
140.	*D. campilla* (Stokes, 1886)	+	+						+
141.	*D. kahli* (Tucolesco, 1962)*		+	+	+	+			
	Fam. Cyclidiidae Ehrenberg, 1838								
142.	*Cristigera vestita* Kahl, 1928		+					+	+
143.	*C. fusiformis* Penard, 1922*	+	+					+	+
144.	*C. media* Kahl, 1928	+					+	+	+
145.	*Caspionella bergeri* (Agamaliev, 1972)	+	+	+	+	+	+	+	+
146.	*Cyclidium citrullus* Cohn, 1865	+	+	+	+	+	+	+	+
147.	*C. glaucoma* Muller, 1786	+	+	+	+	+	+	+	+
	Fam. Uronematidae Thompson, 1964								
148.	*Uronema marinum* Dujardin, 1841	+	+	+	+	+	+	+	+
	Fam. Epistylidae Kahl, 1933								
149.	*Epistylis rotatorium* Kahl, 1935			+				+	+
150.	*E. anastatica* (Linne, 1767)							+	+
151.	*E. dafniae* Fauré-Fremiet, 1905*						+		+
	Fam. Vorticellidae Ehrenberg, 1838								
152.	*Vorticella microstoma* Ehrenberg, 1830		+	+				+	+
153.	*V. similis* Stokes, 1887							+	+
154.	*V. spuripicta* Song et Wilbert, 1889*		+						+
155.	*V. alba* Fromentel, 1874						+	+	+
156.	*Carchesium prechti* Banina, 1977*	+						+	+
157.	*C. umbilicatum* Stiller, 1941	+		+		+	+	+	
	Fam. Zoothamniidae Sommer, 1951								
158.	*Zoothamnium kenti* Leidy, 1874						+	+	+
159.	*Z. adamsi* Stokes, 1885							+	
160.	*Z. haplocaulis* Stiller, 1953*							+	+
161.	*Z. marinum* Mereschekowski, 1877							+	

Table 1, continuation

162.	*Z. carcini* Kent, 1881							+	+
163.	*Z. triophilum* Stiller, 1946*						+	+	
164.	*Z. cupiferum* Stiller, 1986*							+	
165.	Z. *vermicola* Precht, 1935							+	
166.	*Z. haplocaulis* Stiller, 1953							+	
167.	*Z. balticum* Biernacka, 1963							+	+
	Fam. Telotrochidiidae Foissner, 1978								
168.	*Telotrochidium crateriforme* (Muller, 1773)	+					+	+	+
169.	*T. cylindricum* Foissner, 1978*						+	+	
	Total	**58**	**80**	**72**	**84**	**66**	**46**	**71**	**79**

*Notes: 1 – sand; 2 – silty sand; 3 – gray silt; 4 – silt with plants residues; 5 – black silt; 6 – plankton; 7 – periphyton; 8 – thickets of aquatic plants (phytociliocenosis); *species observed for the first time of the Caucasus fauna.*

Thus, species diversity was dominated by benthic biotopes, with the exception of the black silt biotope (33 species), where due to specific conditions, including low oxygen content, and at times the presence of hydrogen sulfide, the species diversity of the ciliates was significantly lower and represented by a characteristic of sapropel species community.

A pairwise comparison of the species richness of communities of free-living ciliates of different biotopes of the Agzibir Lake was carried out. The obtained results showed the greatest similarity of the species richness of benthic biotopes of sand with silty sand (62 %) and silty sand with biotopes of gray silt and silt with plant residues, the similarity with which reached 44 %. The similarity of the species richness of the community of the gray silt biotope and plant residues was also great (56 %).

Consequently, the obtained results indicate a great similarity of the species richness of free-living ciliates between different benthic biotopes. The only exception was the black silt biotope, the similarity of which with the species richness of ciliate communities of other benthic biotopes was 28 % to 34 %. This is due to the specific environmental conditions of the black silt biotope, mainly low oxygen content, and at times the presence of hydrogen sulfide. Obviously, such a gas regime is favorable only for the so-called "Sapropelebiotic" aciliate group such as *Caenomorpha* and *Metopus* species, as well as some eurybiontic representatives of *Loxodes, Spirostomum, Euplotes* species etc.

Comparison of the species richness of various benthos biotopes with plankton showed its minimum similarity with the black silt biotope (6 %) and silty sand (7 %). A bit higher similarity of plankton was with the biotope of silt with plant residues (10 %) and gray silt (13 %).

The similarity of the species richness of the ciliates plankton community with the biotopes of periphyton and phytociliocenosis is much higher and reaches 23 % and 39 % respectively.

Comparison of the ciliate species richness of periphyton with various benthic biotopes showed their similarity in the range from 24 % to 31 %. Higher ones were the ciliates species richness of periphyton with the phytociliocenosis, reaching 38 %.

In order to reveal relationships between different habitats, a cluster analysis of the species richness similarity of free-living ciliates of all studied biotopes was carried out. As it is seen from Fig. 2, the greatest similarity was observed in the cluster that combines benthic biotopes and slightly less similarity was with the black silt biotope, which, as already mentioned, is due to its specific conditions.

The next cluster unites the biotopes of plankton, periphyton and phytociliocenosis, although the ciliates species richness of these three biotopes is lower.

The seasonal dynamics of the development of various biotopes communities of free-living ciliates in Agzibir Lake differs noticeably depending on the species of the biotope (plankton, periphyton, phytociliocenosis, benthos), Fig 3. In addition, the features of this water body (shallow water and connection with the Caspian Sea in spring) also influence the seasonal succession of species composition, changes in the structure of communities, and seasonal changes in total quantity in free-living ciliate communities of different biotopes. Generally, planktonic ciliates of the Agzibir Lake have two maxima of development recorded in spring, with increase in water temperature to +10–13°C and in autumn. Usually, the spring peak is observed in a few days after the spring increase in the water flow of the rivers. The spring water is a source of biogenic elements which together with a number of other factors are impetus to the rapid development of unicellular algae and bacteria, forming the food basis for the organisms that are the first consumers, including ciliates.

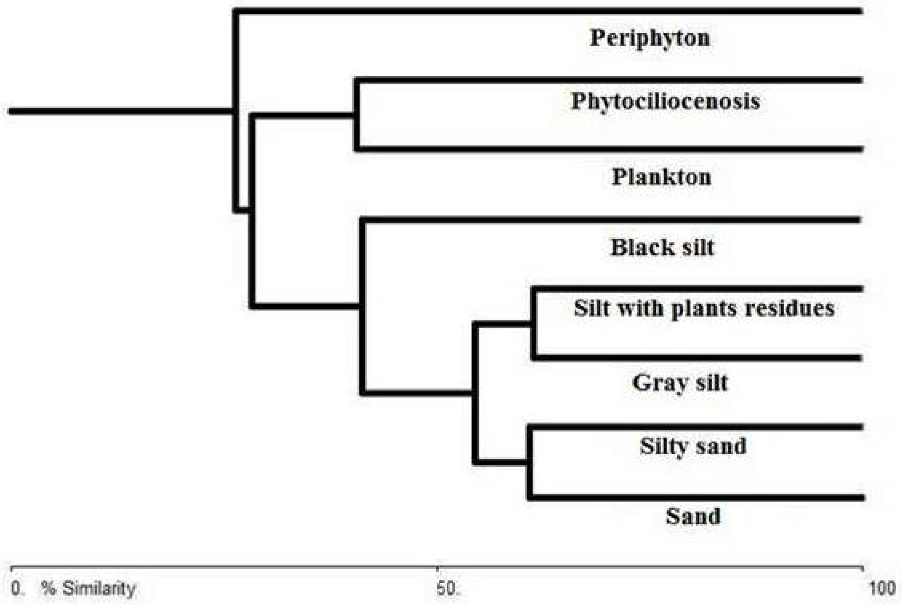

Fig. 2. The similarity of ciliate species richness of different biotopes of the Agzibir Lake

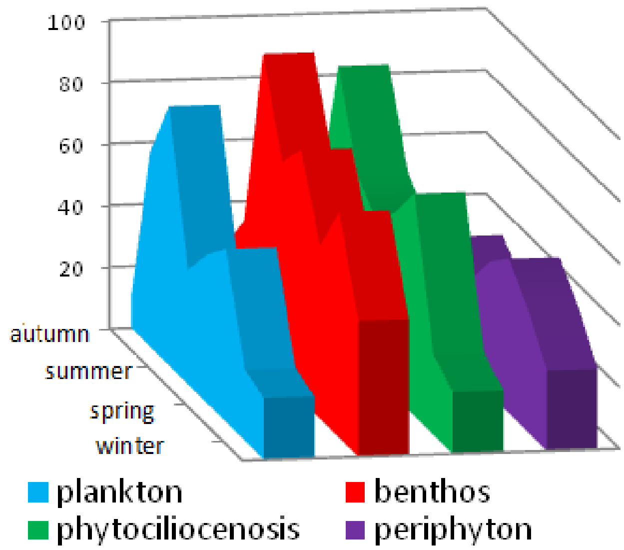

Fig. 3. Seasonal dynamics of the total number (in specimen/liter) of ciliates in various biotopes of the Agzybir Lake (average 2014–2019)

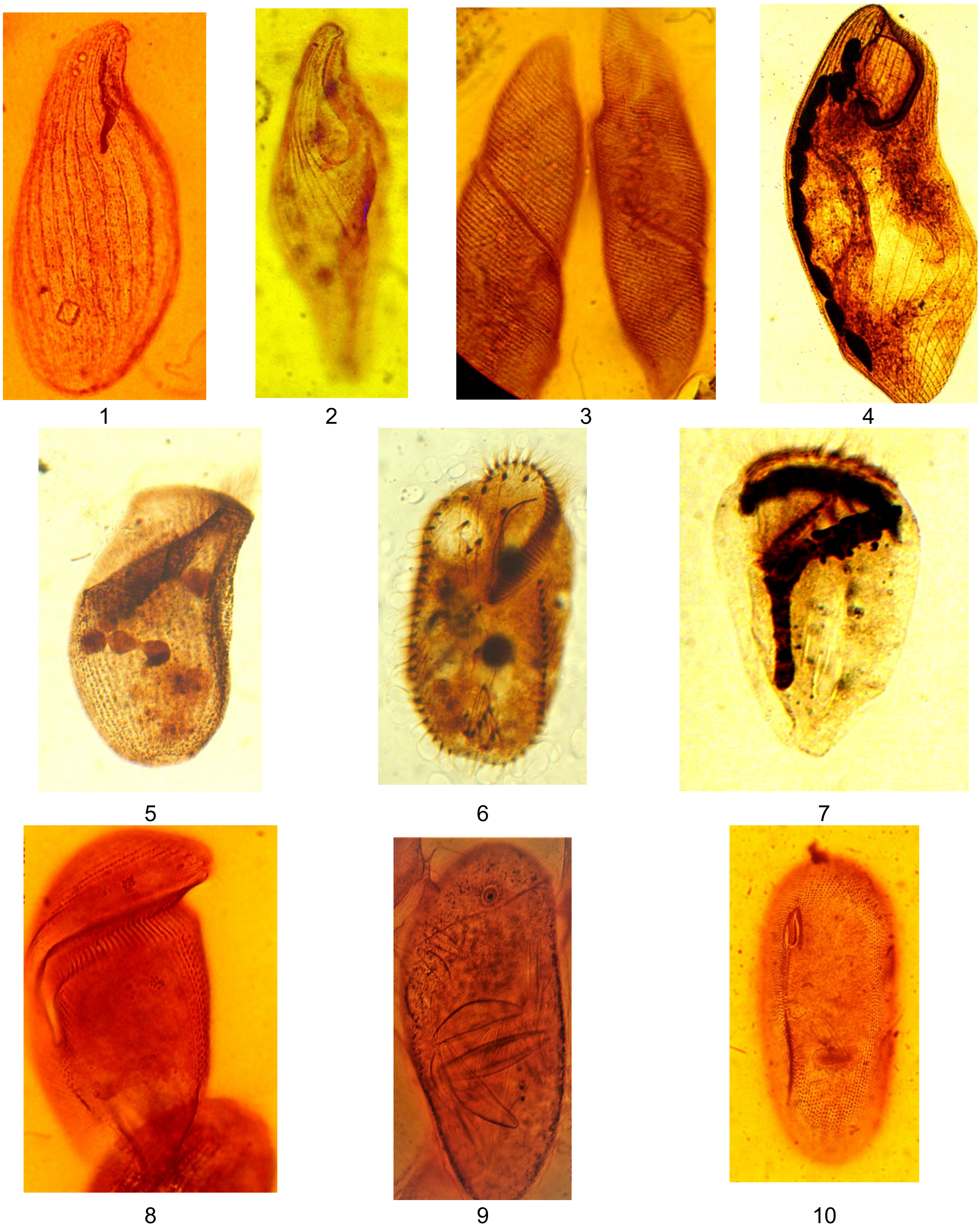

Fig. 4. Some most characteristic ciliates species of the Agzybir lake

1 – *Loxodes striatus*; 2 – *Blepharisma steini;* 3 – *Spirostomum loxodes;* 4 – *Condylostoma magnum*; 5 – *Linostomatella vorticella*; 6 – *Histriculus muscorum*; 7 – *Strombidium apsheronicum*; 8 – *Metopus fuscoides*; *9* – *Zosterodasys cantabrica*; 10 – *Frontonia leucas* (1, 2, 3, 8, 9, 10 – silver nitrate impregnation; 4, 5, 6 – protargol impregnation)

At this time, almost complete replacement of the dominant species occurs in the plankton of the Agzibir Lake usually represented by small species of ciliates as *Halteria, Arcostrombidium, Strombidiopsis, Coleps* and *Holophrya*. Generally, these ciliates are dominant in plankton communities in early spring. Since the end of April, the dominants number has been increasing not only due to true planktonic species, but also due to the mixing of water masses by winds through which many optional species that usually inhabit other biotopes appear in plankton. Among them, the large *Linostomella vorticella, Stentor roeselii,* some *Paraamphisiella, Kahliella* etc. can be noted.

In summer, because of the massive development of unicellular algae, with the increase in temperature to 25–29°C, the water transparency decreases (up to 15–26 cm) and the content of dissolved oxygen reduces. This leads to impoverishment of the species richness of plankton communities of free-living ciliates throughout the Agzibir Lake. At this time, from true plankton species only specimens of *Halteria bifurcata* and *H. cirrifera, Limnostrombidium viride* and *Pelagostrombidium mirabile*, as well as temporary (facultative) species from benthos such as *Zosterodasys mirabilis* and species of *Cristigera* can be found.

In plankton communities, the autumn maximum firstly is due to the development of phytophages and histophages, among which the representatives of *Coleps* are especially prominent.

Unlike planktonic ones, the benthic communities of free-living ciliates in the Agzibir Lake have 3 peaks of development. The first one was observed in spring usually in May, following the development of plankton communities. The change in species composition occurs following the summer increase in water temperature. The basis of the spring benthic ciliates community is formed by such background species as representatives of *Loxodes, Blepharisma, Paragastrostyla, Euplotes*, *Enchelys, Lacrymaria* etc. In summer, as water temperature rises to 21°C and above, destruction processes of organic matter begin to predominate on some benthic biotopes caused by the decrease in the content of oxygen dissolved in water and extinction of aquatic vegetation. This is especially noticeable in the biotopes of the silt with plant residues and black silt. In the latter case, the presence of hydrogen sulfide was recorded at times. During this period, active replacement of dominant species takes place in free-living ciliates community of the both biotopes.

In summer, the first dominants were representatives of "sapropel-bionts" group, among which are species of *Metopus* and *Caenomorpha*. In addition to them, such eurybionts as representatives of *Uronema, Cyclidium* and *Urocentrum*as well as some ciliates of *Frontonia* became dominant. All of these ciliates form the core of the summer benthic community and are the cause of a slight summer increase in total numbers. In autumn, many of the summer benthic ciliate species either completely disappear from the communities or their numbers greatly reduce. At this time, another replacement in species composition takes place and the benthic communities are dominated by the representatives of *Condylostoma, Stentor*, *Aspidisca, Euplotes, Spathidium, Trithigmostoma* and others.

The analysis of the seasonal change results in the ciliate species composition of the phytociliocenosis biotope showed that in this case these changes are similar to those in the plankton. Two maxima development were observed in spring and autumn with the spring peak usually is in advance of the peak in plankton for 8–12 days. Apparently, this is explained by the large and faster heating of water in the thickets of shallow aquatic plants. Moreover, the ciliate species richness of the phytociliocenosis is higher than in plankton and periphyton and this is due to large part of numerous benthic species presence willingly inhabiting this biotope. On the other hand, many rare plankton species such as *Frontonia obtusa, Lembadionlucens*, *Lacrymaria acuta, Amphisiella milnei* etc. also occur in the phytociliocenosis.

Fig. 4 shows microphotographs of some of the most characteristic species of the free-living ciliates of Agzybir Lake, made with total preparations, impregnated with silver nitrate and protargol.

Conclusion

Summarizing all the above mentioned data, certain conclusions can be drawn. The ciliate species diversity of the Agzybir Lake turned out to be quite rich and was represented by 161 species of 42 families. Thirty four species observed for the first time for the Caucasus fauna on the one hand indicate that the survey of free-living ciliates insufficient in our region, and on the other hand, generally favorable conditions for the development of this group of protozoans are present in the Agzibir Lake.

On the grounds prevailing in the lake, the absolute majority of the discovered species (sand, silty sand, gray oily silt with plant residues and black silt) with the largest species diversity was observed in the ciliate benthic community of the gray silt biotope (72 species) and the biotope of silt with plant residues (84 species). This is explained by the gas regime unfavorable for most ciliates species – low oxygen content and the presence of hydrogen sulfide at times, usually in summer, whose presence is able to be tolerated by sapropel ciliates, as well as some other species of eurybionts.

The minimum ciliates species diversity was observed in the plankton and periphyton, 28 and 24 species respectively. One more specific biotope of thickets of aquatic vegetation was identified, for which the term "phytociliocenosis" was proposed, having similarity of species richness to the planktonic and periphyton ciliates communities, 23 % and 39 % respectively.

In quantitative terms, two maxima (in spring and autumn) and minima (winter and summer) were observed in the seasonal dynamics of total quantity of plankton ciliates, and the benthic ciliate communities were characterized by three-peak development, with an additional third summer maximum. In all the studied biotopes of the Agzibir Lake, sequential seasonal succession of species diversity was observed depending on the season and a constant change of some species. In our opinion, this is primarily explained by the trophic factor – the presence of food objects for a particular species, as well as by more general causes such as the temperature factor and gas regime.

The obtained data testifies the important role of free-living ciliates in the production and destruction processes of water bodies, which must be taken into account in general hydrobiological investigations.

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Сезонні зміни спільнот вільноживучих інфузорій різних біотопів озера Агзибір

І.Ф. Мансімова, І.Х. Алекперов

Озеро Агзибір є за рядом гідрохімічних і гідробіологічних чинників оптимальним для формування високого біорізноманіття вільноживучих інфузорій. Цьому сприяє і постійне надходження біогенних елементів в результаті метаболізму великих колоній птахів та гниючих органічних залишків рослинного і тваринного походження. Озеро Агзибір, що має зв'язок з Каспійським морем навесні і восени, є місцем нересту і подальшого розвитку личинок багатьох цінних риб Каспійського моря, для яких інфузорії є вихідним кормом на ранніх етапах онтогенезу. Всього в період 2014–2019 рр. нами були знайдені 169 видів вільноживучих інфузорій, з яких 34 нами відзначені вперше для фауни Каспійського моря. Найменше видове різноманіття спостерігалося в планктоні, де було зареєстровано 46 видів. У бентосі на піщаному біотопі були відзначені 58 видів, а на замуленому піску – 80 видів. На мулових ґрунтах у біотопі сірого мулу нами відзначено 72 види, у біотопі мулу з рослинними залишками спостерігалося максимальне видове різноманіття – 84 види, а на чорному мулі з ділянками сапропелю було знайдено 66 видів вільноживучих інфузорій. У біотопі перифітону нами був відзначений 71 вид, а в прибережних заростях водоростей (фітоциліоценозах) всього знайдено 79 видів вільноживучих інфузорій. Так само, як і біотоп піску, біотоп чорного мулу, іноді з невеликими ділянками сапропелевого мулу, за площею сильно поступається іншим бентичним біотопам озера Агзибір. Спільнота вільноживучих інфузорій чорного мулу досить специфічна і містить багато видів, стійких до низьких величин розчиненого у воді кисню і вмісту в воді сірководню. Сезонні зміни загальної чисельності вільноживучих інфузорій бентичних біотопів мають три максимуми, що припадають на весну, літо і осінь. В інших біотопах планктону, перифітону і фітоциліоценозів були відзначені тільки два максимуми, які припадають на весну та осінь. Найбільша подібність видового різноманіття спостерігалася у бентичних спільнотах. Найнижча схожість спостерігалась між сапропелевим мулом та іншими. Як уже згадувалося, це пов'язано із специфічними екологічними умовами біотопу сапропелевого мулу.

Ключові слова: *озеро Агзибір, Азербайджан, планктон, бентос, перифітон, біотоп, інфузорії, сезонні зміни.*

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Сезонные изменения сообществ свободноживущих инфузорий различных биотопов озера Агзыбир

И.Ф. Мансимова, И.Х. Алекперов

Озеро Агзыбир является по ряду гидрохимических и гидробиологических факторов оптимальным для формирования высокого биоразнообразия свободноживущих инфузорий. Этому способствует и постоянное поступление биогенных элементов в результате метаболизма больших колоний птиц и гниющих органических остатков растительного и животного происхождения. Озеро Агзыбир, имеющее связь с Каспийским морем весной и осенью, является местом нереста и последующего развития личинок многих ценных рыб Каспийского моря, для которых инфузории являются исходным кормом на ранних этапах онтогенеза. Всего в период 2014–2019 гг. нами были найдены 169 видов свободноживущих инфузорий, из которых 34 нами отмечены впервые для фауны Каспийского моря. Наименьшее видовое разнообразие наблюдалось в планктоне, где было зарегистрировано 46 видов. В бентосе на песчаном биотопе были отмечены 58 видов, а на заиленном песке – 80 видов. На иловых грунтах в биотопе серого ила нами отмечено 72 вида, в биотопе ила с растительными остатками наблюдалось максимальное видовое разнообразие – 84 вида, а на черном иле с участками сапропеля было найдено 66 видов свободноживущих инфузорий. В биотопе перифитона нами был отмечен 71 вид, а в прибрежных зарослях водорослей (фитоцилиоценозах) всего найдено 79 видов свободноживущих инфузорий. Так же, как и биотоп песка, биотоп черного ила, иногда с небольшими участками сапропелевого ила, по площади сильно уступает остальным бентическим биотопам озера Агзыбир. Сообщество свободноживущих инфузорий черного ила достаточно специфично и включает многие виды, устойчивые к низким величинам растворенного в воде кислорода и содержанию в воде сероводорода. Сезонные изменения общей численности свободноживущих инфузорий бентических биотопов имеют три максимума, приходящиеся на весну, лето и осень. В остальных биотопах планктона, перифитона и фитоцилиоценозов были отмечены только два максимума, приходившиеся на весну и осень. Наибольшее сходство видового разнообразия наблюдалось в бентических сообществах. Самое низкое сходство наблюдалось между сапропелевым илом и остальными. Как уже упоминалось, это связано со специфическими экологическими условиями биотопа сапропелевого ила.

Ключевые слова: *озеро Агзыбир, Азербайджан, планктон, бентос, перифитон, биотоп, инфузории, сезонные изменения.*

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