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INVESTIGATION OF DIFFERENT ENVIRONMENTAL FACTORS ROLE IN THE FORMATION OF ZOOPLANKTON COMMUNITY IN THE ARPA RIVER (ARMENIA) AND ITS MAIN TRIBUTARIES

A. H. HAYRAPETYAN [1*], S. E. BOLOTOV [2], G. A. GEVORGYAN [1], B. K. GABRIELYAN [1]

[1] *Scientific Center of Zoology and Hydroecology of NAS RA*
[2] *I.D. Papanin Institute for Biology of Inland Water of RAS*

The role of different environmental factors in the formation of zooplankton community in the river ecosystems of the Arpa River catchment basin was investigated. The results of the study showed that zooplankton diversity in the mentioned ecosystems was significantly affected by the river velocity, which caused not only deterioration but also improvement in the status of zooplankton diversity. It was also revealed that the main environmental factors determining the species structure of zooplankton community in the Arpa, Yeghegis and Darb rivers were oxygen saturation, total phosphorus, total suspended solids and organic matter (of terrigenous origin probably).

Keywords: Arpa River, tributaries, environmental factors, zooplankton community, diversity index, Canonical correspondence analysis.

Introduction. The Arpa River catchment basin is situated in the southeastern part of Armenia. The Arpa River originated from South-East of the Vardenis mountain is one of the major tributaries of the transboundary Araks River in the territory of Armenia. The river length is 126 *km* (90 *km* in Armenia), catchment basin is 2630 *km*². The Darb and the Yeghegis Rivers are the main tributaries of the Arpa River. River waters in the Arpa River catchment basin are mainly used for irrigation and energetic purposes [1]. Aquatic biodiversity and ecosystems in the Arpa River catchment basin are negatively affected due to the insufficient management of water resources and anthropogenic discharges [2].

Zooplankton community is one of the most important components of hydro-ecosystems. It has a significant role in the formation of trophic interrelationships and self-purification processes in water bodies [3, 4]. Zooplanktonic organisms being small-sized animals have intense metabolic and filtration activities [5].

Compared with lentic waters, the physical environment of lotic systems is unfavorable for zooplankton to keep their position in water [6]. Thus, hydrological parameters are considered as the most powerful environmental factors limiting zooplankton production and distribution in rivers [7]. However, these facts are focused on large lowland rivers, and relatively little is known about the temporal and spatial distribution of zooplankton in small river ecosystems typical for PA [8, 9].

* E-mail: armmino@yandex.ru

The species composition and quantitative parameters of aquatic organisms are formed by the impact of different environmental factors. The investigation of the growth rates of hydrobiots is actual especially for small rivers, where living conditions under anthropogenic pressures are changed quickly. Therefore, the investigation of biological communities in the aquatic ecosystems of the Arpa River catchment basin is urgently required and has a high scientific importance. The aim of the present study was to investigate the role of different environmental factors in the formation of zooplankton community in the river ecosystems of the Arpa river catchment basin.

Materials and Methods. Hydrochemical and hydrophysical investigations were carried out in 11 monitoring points, 9 of which were chosen as sampling points for zooplankton study (Tab. 1). Zooplankton samplings (totally 45 samples) were done in June, October, 2012 and April, May and September, 2013.

Table 1

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

Sampling point	River site location (coordinates: latitude and longitude)
A1	the Arpa River site located about 5 *km* upstream from Jermuk Town (39°87'49.09"; 45°72'08.27")
A3	the Arpa River site located about 0.5 *km* upstream from the point of the confluence of the Arpa and the Darb Rivers (39°69'63.83"; 45°55'98.17")
A4	the Darb River site located about 0.5 *km* upstream from Ughedzor Village (39°69'10.38"; 45°68'94.25")
A5	the Darb River site located about 0.5 *km* upstream from the river mouth (39°69'20.23"; 45°56'26.10")
A6	the Arpa River site located about 0.5 *km* upstream from Vayk Town (39°68'17.50"; 45°48'69.67")
A8	the Arpa River site located about 5 *km* upstream from the point of the confluence of the Arpa and the Yeghegis Rivers (39°74'09.41"; 45°34'46.88")
A9	the Yeghegis River site located about 1 *km* upstream from the river mouth (39°75'15.83"; 45°31'04.67")
A10	the Yeghegis River site located about 5 *km* upstream from Getikvank Village (39°94'07.80"; 45°51'42.30")
A11	the Arpa River site located about 1.5 *km* downstream from Areni Village (39°71'99.91"; 45°16'67.83")

Water samples, for zooplankton analysis, were taken with a bucket, which were filtered through a plankton net (60 μm) and fixed with formalin solution (4–5% final concentration). The further processing of the samples was carried out by standard methods accepted in hydrobiology [6, 7]. The qualitative and quantitative analyses of zooplankton were done by a microscope using "Bogorov" camera. Zooplankton species identification was performed by using appropriate identification keys [8–10]. The parameters for quantitative studies were abundance N (ind/m^3) and biomass B (mg/m^3) determined on the basis of the relation between length and weight of the body [11]. Status of zooplankton species diversity was assessed based on the Shannon–Wiener diversity index (HN) [12].

Canonical correspondence analysis (CCA) was done using CANOCO 4.5 software to examine the effect of environmental factors (water temperature, T), electrical conductivity, colour, transparency, total dissolved solids (TDS) and total suspended solids (TSS), pH, dissolved oxygen (DO), oxygen saturation (OS), chemical and 5-day biochemical oxygen demand (COD_{Cr} and BOD_5 respectively),

ammonium (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), phosphate (PO_4^{3-}), chloride and sulphate ions, total phosphorus (P_{tot})) on the formation of zooplankton community. All the environmental variables were tested through a forward selection procedure. Statistically significant variables ($p<0.05$) were assessed by Monte-Carlo tests (999 permutations) and were included in further analysis. Physico-chemical data used in the CCA analysis were provided by the Environmental Impact Monitoring Center of the Ministry of Nature Protection of RA.

River velocity in the selected observation site was determined by the following technique: a bobber was vented from the selected point of the river, and the distance covered by the bobber within the selected time of period was measured.

Results and Discussion. During the investigation period 23 zooplankton species belonging to 23 genera of 17 families of *Rotifera*, *Cladocera* and *Copepoda* main groups were recorded in the samples (Tab. 2).

Table 2

Taxonomic groups of zooplankton community in the investigated river ecosystems of the Arpa River catchment basin

Taxonomic group	Sampling point								
	A1	A3	A4	A5	A6	A8	A9	A10	A11
Rotifera									
Cephalodella gibba (Ehrenberg, 1830)*	+	+	+	–	+	+	+	–	+
Euchlanis dilatata (Ehrenberg, 1832)*	+	+	+	+	+	+	+	+	+
Eosphora sp.	–	–	–	–	+	–	–	–	–
Trichocerca longiseta (Schrank, 1802)*	–	–	–	–	–	–	–	–	+
Dicranophorus sp.	–	–	–	–	–	–	–	–	+
Notommata aurita (Müller, 1786)	+	–	–	–	+	–	–	–	+
Polyarthra dolichoptera (Jdelson, 1925)*	–	+	–	–	+	–	–	+	–
Hexarthra mira (Hudson, 1871)	–	–	–	–	+	–	–	–	–
Keratella quadrata (Müller, 1786)*	–	–	–	–	+	–	–	–	–
Asplanchna priodonta (Gosse, 1850)*	–	–	–	–	+	+	–	–	+
Lecane luna (Müller, 1776)*	–	–	–	–	–	+	–	–	+
Trichotria pocillum (Müller, 1776)*	+	–	+	+	–	+	–	–	–
Conochilus unicornis (Rousselet, 1892)*	–	–	–	–	–	–	–	–	+
Cladocera									
Daphnia hyalina (Leydig, 1860)*	–	–	–	–	+	–	–	–	–
Bosmina longirostris (Müller, 1785)*	–	–	–	–	+	+	–	–	+
Simocephalus expinosus (De Geer, 1778)	–	+	–	–	–	–	–	–	–
Alona rectangula (Sars, 1862)*	–	+	+	–	+	+	–	–	–
Chydorus sphaericus (Müller, 1785)*	–	–	+	–	+	+	–	–	–
Pleuroxus truncatus (Müller, 1785)*	–	–	–	–	–	+	–	–	–
Copepoda									
Paracyclops fimbriatus f. (Fischer, 1853)	–	–	+	+	–	+	–	–	–
Macrocylops albidus (Jurine, 1820)	–	+	+	–	–	–	–	–	–
Cyclops sp.	–	+	–	–	+	–	–	–	–
Eudiaptomus gracilis (Sars, 1863)*	–	–	–	–	+	–	–	–	–

* indicator species; + registered; – not registered

Rotifera was quantitatively dominant (40–100%) group in the zooplankton community of the rivers, and the representatives of the genus *Euchlanis* recorded in all the river observation points in different months were the most widespread organisms in the river waters, the representatives of the genus *Cephalodella* were

the second most widespread organisms (Tab. 2). These organisms have a wide range of tolerance (high ecological amplitude), which explains their wide distribution in the river waters [8].

During the investigation period the highest species diversity of zooplankton (14 species, 9 of which were water quality indicators) was recorded in the sampling point A6 (Tab. 2). Most of the recorded species are the indicators of oligo-mesotrophic conditions [13–16].

The highest quantity of zooplanktonic organisms was recorded in the river observation point A8 in September, when the species *Euchlanis dilatata* was prevalent (98%) (Tab. 3). This species is eurythermic and eurytopic and grows well in river sites rich in aquatic vegetation. It's mostly observed in oligo-beta-mezosaprobic waters.

The highest biomass of zooplankton was recorded in the sampling point A6 in May: the species *Eudiaptomus gracilis* was prevalent (35%) (Tab. 3). This species is widely diffused throughout Europe, but it is relatively new in Armenia: it was recorded for the first time in 2004 [17, 18]. The species *E. gracilis* is commonly observed in the mesotrophic and eutrophic environments, it is a typical filtrator and quite sensitive to temperature variations [19]. The domination of the species *E. gracilis* was probably conditioned by the low value of river velocity (V=0.02 *m/s*), as well as by the prevailing position of quantity of diatomic algae in phytoplankton (54%) [2]. Diatoms play a leading role in the ration of the mentioned zooplankton species.

The lowest quantitative parameters during the investigation period were mostly recorded in the observation points A9 and A10, which was probably due to the comparatively high values of river velocity in these observation points (0.21–0.25 *m/s*) (Tab. 3).

Table 3

Quantity (N, ind/m^3) and biomass (B, mg/m^3) of zooplankton in the river ecosystems of the Arpa River catchment basin

Sampling point	06.2012		10.2012		04.2013		05.2013		09.2013	
	N	*B*	*N*	*B*	*N*	*B*	*N*	*B*	*N*	*B*
A1	6.5	3.61	66.6	0.37	57.0	0.07	0.0	0.000	340.0	0.60
A3	7.8	0.08	199.8	31.90	0.0	0.00	243.0	0.600	1280.0	2.60
A4	7.8	0.27	133.2	0.30	0.0	0.00	0.0	0.000	2620.0	24.70
A5	2.6	0.01	0.0	0.00	0.0	0.00	40.0	4.000	215.0	0.80
A6	7.8	0.03	965.7	1.90	2244.0	25.66	644.0	48.300	1515.0	3.80
A8	0.0	0.00	99.9	0.20	163.0	1.68	480.0	3.600	12559.0	26.30
A9	1.3	0.001	0.0	0.00	0.0	0.00	0.0	0.000	20.0	0.04
A10	0.0	0.00	33.3	0.07	0.0	0.00	14.0	0.010	0.0	0.00
A11	22.1	0.17	0.0	0.00	20.0	0.40	0.0	0.000	422.0	0.80

The HN index was applied to assess the status of zooplankton diversity in the investigated river ecosystems of the Arpa River catchment basin. According to the HN values of zooplankton, the highest species diversity in different months was recorded in the river sampling points A3, A4 and A6. Zooplankton diversity deterioration in different months was registered in all the investigated river observation points, however, the species diversity deterioration in the observation points of the Yeghegis River (sampling points A9 and A10) was observed during

the whole period of the investigation. The single specimens of zooplanktonic organisms in the Yeghegis river observation sites were registered, as a result of which the diversity index values in these river sites were zero (Fig. 1). The main environmental factor affecting zooplankton diversity in the investigated river ecosystems of the Arpa River catchment basin was probably river velocity, which not only limited the growth of zooplankton, ranging 0.18–0.25 *m*/*s*, but also caused an improved development of planktonic invertebrates, ranging 0.01–0.04 *m*/*s*.

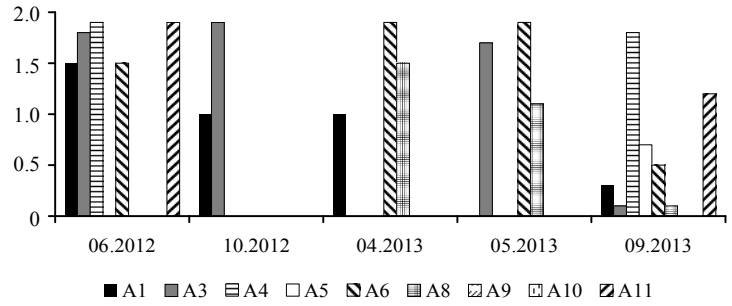

Fig. 1. Diversity index values of zooplankton in the investigated river ecosystems of the Arpa River catchment basin.

Based on literature data analysis, the list of the zooplankton indicator species of different trophic and saprobic degrees has been developed [14–16, 20]. During the investigation period, the 23 species of zooplanktonic organisms were found in the Arpa, the Darb and the Yeghegis Rivers, 14 of which were indicator species and indicated about oligo-betta-mezosaprobic conditions in the river observation points A1, A5, A8, A9, A10, A11 and about betta-mezosaprobic conditions in the observation points A3, A4 and A6 (Tab. 2). Thus, most of zooplankton species registered in the rivers are typical for organically polluted waters, which allows to conclude that organic matter was one of the main factors forming the species structure of zooplankton community in the Arpa River catchment basin.

Canonical correspondence analysis (CCA) was applied to reveal main environmental factors forming zooplankton community in the investigated rivers. For CCA ordination, the species-environmental biplot shows the relations of the species and environmental variables with the ordination axes (Fig. 2). The length of the arrow indicates the relative importance of environmental variable in determining the axes. The position of the species centers (points) along the ordination axes represents their respective optima along the environmental gradient.

The axis 1 was correlated well with OS and T, and the species *Cephalodella gibba*, *Euchlanis dilatata*, *Conochilus unicornis* and *Pleuroxus truncatus* had the highest values on this axis. The axis 2 was well correlated with PO_4^{3-} and P_{tot}, and the species having high correlation with this axis were *Paracyclops fimbriatus*, *Lecane luna*, *Chydorus sphaericus* and *Trichotria pocillum* (Fig. 2, a).

The investigated river observation points were also "gravitate" to specific environmental factors determining the species structure of zooplankton community in each particular site and were characterized by a set of priority environmental conditions. It is shown that the zooplankton community in the river observation points A1 and A11 were "gravitate" to the complex of factors: transparency, colour, NH_4^+ and TSS (Fig. 2, b).

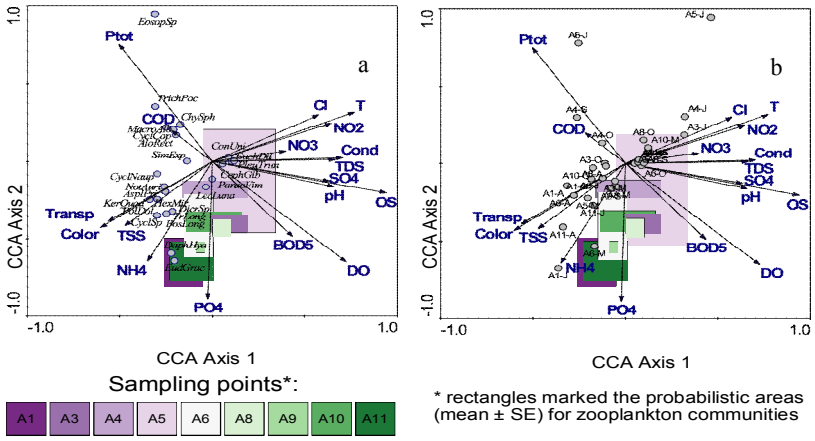

Fig. 2. Results of the CAA of zooplankton community in the investigated river ecosystems of the Arpa River catchment basin.

According to the results of CCA, the main environmental factors determining the species structure of zooplankton community in the investigated river ecosystems of the Arpa River catchment basin were OS, P_{tot}, TDS and COD_{Cr} (probably terrigenous origin) (Tab. 4).

Table 4

Environmental factors determining the species structure of zooplankton community in the investigated river ecosystems of the Arpa River catchment basin

Variable	λ_A Variance explained	Significance		Variable	λ_A Variance explained	Significance	
		P	F			P	F
OS	0.81	0.001	6.19	NO_3^-	0.08	0.560	0.82
P_{tot}	0.62	0.003	5.51	PO_4^{3-}	0.08	0.465	0.86
TDS	0.41	0.003	4.07	NH_4^+	0.10	0.455	0.94
COD_{Cr}	0.18	0.049	1.83	DO	0.08	0.532	0.84
Colour	0.13	0.217	1.32	T	0.13	0.155	1.46
Transparancy	0.13	0.144	1.33	NO_3^-	0.07	0.665	0.67
pH	0.10	0.298	1.15	BOD_5	0.05	0.780	0.52
Chloride	0.12	0.227	1.21	Sulfate	0.15	0.162	1.52
TDS	0.08	0.449	0.91	Conductivity	0.10	0.334	1.10

Conclusion. In general, it's possible to state that zooplankton diversity in the investigated river ecosystems of the Arpa River catchment basin was significantly affected by the river velocity, which caused not only deterioration, but also improvement in the status of zooplankton diversity. It was also revealed that the main environmental factors determining the species structure of zooplankton community in the Arpa, the Darb and the Yeghegis Rivers were oxygen saturation, total phosphorus, total suspended solids and organic matter.

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