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### Article

## Revisiting the Yeghegis River for the purposes of hydrobiological monitoring

M.R. Dallakyan , Z.H. Mkrtchyan\* , H.V. Yepremyan ,  
H.H. Kobelyan , L.N. Poghosyan , V.L. Asatryan 

*Scientific Center of Zoology and Hydroecology of the National Academy of Sciences of the Republic of Armenia, Sevak St. 7, Yerevan, 0014 Armenia*

\*zhanna.mkrtchyan@gmail.com

**Abstract.** Due to initiated in 2011 improvements in the water management system of Armenia, six Basin Management Areas were created and hydrobiological monitoring was introduced. It requires regular investigations of ecological status of surface water bodies. The current research aims to study the changes in the assemblage of benthic macroinvertebrates in the basin of the Yeghegis River ten years after the baseline studies. The results show higher taxonomic diversity for this basin in comparison with 2012. However, significant changes in its overall ecological status have not been revealed. This proves the assumption that existing multimetric index can be still used for the Ararat Basin Management Area, but further investigations of species structure of benthic macroinvertebrates are necessary to improve its performance.

**Keywords:** ecological status, Ararat Basin Management Area, The Arpa River, Biological Quality Elements, benthic macroinvertebrates, Water Framework Directive, bioindication, EPT

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### ORCID:

M.R. Dallakyan, <https://orcid.org/0000-0001-8269-8227>

Z.H. Mkrtchyan, <https://orcid.org/0009-0008-3605-1391>

H.V. Yepremyan, <https://orcid.org/0009-0005-4038-6555>

H.H. Kobelyan, <https://orcid.org/0009-0003-9618-6566>

L.N. Poghosyan, <https://orcid.org/0009-0008-4933-0568>

V.L. Asatryan, <https://orcid.org/0000-0002-1477-5742>

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*Научная статья***Исследование реки Ехегис в целях гидробиологического мониторинга**

М.Р. Даллакан<sup>id</sup>, Ж.Г. Мкртчян\*<sup>id</sup>, Э.В. Епремян<sup>id</sup>,  
Р.О. Кобелян<sup>id</sup>, Л.Н. Погосян<sup>id</sup>, В.Л. Асатрян<sup>id</sup>

*Научный центр зоологии и гидроэкологии Национальной академии наук Республики Армения, 0014, Республика Армения, г. Ереван, ул. П. Севака, д. 7*

\*zhanna.mkrtchyan@gmail.com

**Аннотация.** С 2011 г. ведутся работы по улучшению системы управления водными ресурсами Армении, в результате которых территория республики разделена на шесть территорий управления речными бассейнами и основана государственная система гидробиологического мониторинга, требующая регулярного исследования экологического состояния поверхностных водных объектов. Данная работа посвящена оценке изменений в сообществе донных макробеспозвоночных в бассейне реки Ехегис спустя десятилетие после первоначальных исследований. Результаты показывают более высокое таксономическое разнообразие по сравнению с 2012 г., однако существенных изменений в общем экологическом состоянии не выявлено. Это подтверждает возможность дальнейшего использования упрощенного мультиметрического индекса, разработанного для управления Араратским речным бассейном. В то же время необходимы дополнительные исследования видового состава донных макробеспозвоночных для повышения эффективности индекса.

**Ключевые слова:** экологическое состояние, Араратский речной бассейн, река Арпа, элементы биологического качества, донные макробеспозвоночные, Водная Рамочная Директива, биоиндикация, ЕРТ

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**ORCID:**

М.Р. Даллакян, <https://orcid.org/0000-0001-8269-8227>

Ж.Г. Мкртчян, <https://orcid.org/0009-0008-3605-1391>

Э.В. Епремян, <https://orcid.org/0009-0005-4038-6555>

Р.О. Кобелян, <https://orcid.org/0009-0003-9618-6566>

Л.Н. Погосян, <https://orcid.org/0009-0008-4933-0568>

В.Л. Асатрян, <https://orcid.org/0000-0002-1477-5742>

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## Introduction

The maintenance of the quality of freshwater ecosystems is of paramount importance both for the humanity and the ecosystems (Loucks and van Beek, 2017). Hence, the Government of the Republic of Armenia (RA) adopted the decree № 75-N<sup>1</sup> in 2011 and amended Water code in 2022 aimed at ensuring a good quality for surface water bodies in accordance with the European Union Water Framework Directive (EU WFD 2000/60/EC, 2000)<sup>2</sup> requirements. To improve water management system in Armenia, six river basin management areas (RBMA's) have been established and the baseline studies have been performed there to establish Basin Management Plans (BMPs). However, BMPs should be revised once per six years and the assessment of the ecological status of surface water bodies is a core component of such revisions. There are different approaches to the assessment of surface water bodies health (e.g. Peluso et al., 2021; Yan et al., 2022). In hydrobiological monitoring, the most reliable ones are multimetric and multivariate approaches (e.g. Arman et al., 2019; Birk et al., 2012; Ndatimana et al., 2023). They were tested in different river basins of Armenia (Asatryan and Dallakyan, 2015, 2018, 2021).

The Yeghegis River is the biggest tributary of the Arpa River – the largest surface water body in the “Ararat RBMA” and one of the major water veins of the RA of an international interest. The baseline hydrobiological studies in the Arpa River, involving its Yeghegis tributary, were conducted in 2012 that contributed to the development of a simplified multimetric index (MMI) for the assessment of the ecological status of the rivers in the basin (Asatryan and Dallakyan, 2021) based on the benthic macroinvertebrates. Benthic macroinvertebrates assemblages are used worldwide not only for MMIs (Birk et al., 2012), but for the development of simple biotic indices (Barbour et al., 1999) and Rapid Biological Assessments (RBA) tested in Armenia as well (e.g. Asatryan et al., 2020)

Considering the geopolitical situation, which directly influences Vayots Dzor province where the Arpa River runs, ten years after the baseline studies we revisited the Yeghegis for more detailed studies of the assemblage of benthic macroinvertebrates in the RBMA. Thus, the aim of the study was to investigate the changes in the assemblage of benthic macroinvertebrates in the drainage basin of the Yeghegis River ten years after the baseline studies. Also, the current study aims to fulfill the gap in the knowledge on the best available sites in the “Ararat RBMA” important for further improvement of the multimetric index performance.

## Materials and methods

### *Study area and sampling sites*

The Yeghegis River starts from the southern slopes of the Vardenis range at an altitude of 3200 m a.s.l. The length of the river is 47 km and the drainage basin area is 516 km<sup>2</sup>. Most of the upper course part flows through the canyon and V shape valley thus creating many rapids and having a significant hydroenergetic potential. Thereby, several small hydropower plants (SHPPs) have already been established on the river and hydromorphological degradation along with hydropeaking effects are the main threats to the ecosystem of the river (Gevorgyan et al., 2017; Hambaryan and Gevorgyan, 2019).

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<sup>1</sup> The RA Government Decree N75-N of 27 March 2011 "On the establishment of water quality standards for each water basin management area depending on the territory".

<sup>2</sup> European Commission Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy.

Field studies were carried out at the beginning of August 2022 (when the river was in low water condition) with the observance of all safety requirements of the AQEM protocol<sup>3</sup>. The season coincided with the period of baseline study conducted in 2012. However, in 2022 we collected benthic macroinvertebrates from six stations instead of two used in 2012 and constructed the network of sampling sites to cover a range of altitudes and anthropogenic impacts. A special focus was on observing the changes of benthic macroinvertebrates upstream and downstream from dams of hydropower plants widely spread across the drainage basin of the Yeghegis River. Sampling sites coordinates and altitudes were recorded by the Garmin eTrex 20 GPS (Table 1).

Downstream from station Y3, stones were covered by *Cladophora* sp. having the cover area of 60–70% in stations Y5, Y6. Some submerged macrophytes of *Ranunculus* and *Veronica* genera covered large areas at stations Y3 and Y4, while there were almost no submerged macrophytes at stations Y1 and Y2.

The Hierarchical cluster analysis of sampling sites to get the level of their similarities and to analyze the potential impact of microhabitat conditions on the diversity of benthic macroinvertebrates among stations was conducted based on microhabitat conditions and with the use of the squared Euclidean distance in IBM SPSS 17 software.

### Sampling and processing of benthic macroinvertebrates

Samples of benthic macroinvertebrates were collected by the Surber sampler with the mesh size of 500 µm and frame size of 0.09 m<sup>2</sup> by five replications following the standards of EN 16150:2012<sup>4</sup>. Samples were then processed in the field and preserved in the 96% ethanol for further identification to the same taxonomic unit as in 2012 (mostly genus). Identification was conducted under the Zeiss Stemi 305 microscope using the identification Keys (e.g. Bikashvili et al., 2022; Hrivniak et al., 2018; Ivanov, 2001; Kutikova and Starobogatov, 1977; Waringer and Graf, 2011).

### Assessment of ecological status

Following the methods used for the baseline assessment in 2012, the ecological status of investigated stretches was estimated by the BMWP (Armitage et al., 1983) and ASPT (Semenchenko and Razlucky, 2010) (Tables 2 and 3) indices.

$$BMWP = \sum_{i=1}^n T_i,$$

where  $T_i$  is a tolerance score according to Wright et al. (1993) and Leeds-Harrison et al. (1996).

$$ASPT = \frac{BMWP}{N_{taxa}},$$

where “ $N_{taxa}$ ” is the number of taxa in the sample.

Also we calculated Number of taxa, Number of families, % share of Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa and % share of Diptera taxa (excluded Blephariceridae) metrics. To compare the structure of benthic macroinvertebrates among different stations Sørensen–Dice index (Sørensen, 1948) was applied:

$$K = \frac{2J}{A + B},$$

where  $J$  is the number of taxa common for the both sites,  $A$  and  $B$  are the total number of taxa at each site.

<sup>3</sup> Manual for the application of the AQEM system, 2002. A comprehensive method to assess European streams using benthic macro invertebrates, developed for the purpose of the Water Framework Directive, Version 1.0. Интернет-ресурс. URL: [http://www.aqem.de/ftp/aqem\\_manual.zip](http://www.aqem.de/ftp/aqem_manual.zip) (accessed: 05.02.2019).

<sup>4</sup> EN 16150:2012. Water quality – Guidance on pro-rata multi-habitat sampling of benthic macro-invertebrates from wadeable rivers.

**Table 1.** The sampling sites' coordinates, altitudes and some basic abiotic characteristics. Substratum is classified according to the AQEM protocol, where the size descriptors are the following: silt/sand < 2 mm; akal 0.2–2 cm; microlithal 2–6 cm; mesolithal 6–20 cm; macrolithal 20–40 cm; megalithal > 40 cm; hygropetric sites – water layer on solid substrate. \* – site was also studied in 2012.

Sampling site	Latitude	Longitude	Altitude (m a.s.l.)	T (°C)	Riverbed width (m)	Average depth (cm)	Velocity (m/sec)	pH	Substratum
Y1*	39.9268	45.5169	2235	16.7	4.5	35	0.8	8	sand 10%; akal 5%; microlithal 10%; mesolithal 30%; macrolithal 10%; megalithal 25%; скальное дно 10%
Y2	39.9239	45.5114	2199	17.8	3.5	25	0.4	8	sand 10%; microlithal 10%; mesolithal 30%; macrolithal 30%; megalithal 10%; hygropetric sites – water layer on solid substrate 10%
Y3	39.8695	45.3541	1525	18.5	15	45	0.3	7.9	sand/silt 30%; akal 20%; microlithal 20%; mesolithal 20%; macrolithal 10%
Y4	39.8670	45.3509	1520	18.4	7	25	0.4	7.9	sand 10%; akal 5%; microlithal 20%; mesolithal 20%; macrolithal 25%; megalithal 20%
Y5	39.8238	45.2972	1232	18.7	14	25	0.7	7.8	microlithal 10%; mesolithal 20%; macrolithal 40%; megalithal 20%; hygropetric sites – water layer on solid substrate 10%
Y6*	39.8206	45.2965	1228	18.7	9	25	0.7	7.8	microlithal 10%; mesolithal 20%; macrolithal 50%; megalithal 20%

**Table 2.** BMWP scores and the ecological status class.

BMWP scores	Ecological status
> 150	Excellent
101–150	Very good
51–100	Good
26–50	Not High
< 25	Poor

**Table 3.** ASPT scores and the ecological status class.

ASPT scores	Ecological status
5+	Excellent
4.5–4.9	Very good
4.1–4.4	Good
3.6–4	Moderate
3.1–3.5	Rather poor
2.1–3	Poor
0–2	Very poor

## Results and discussion

As a result of the analysis of qualitative and quantitative structures of benthic macroinvertebrates (Table 4), the overall pattern of decrease in diversity was revealed both towards the lower course parts (from Y1 to Y6) and in the sampling sites upstream from the dams (Y3, Y5) where water stagnates. Such a pattern of changes is typical not only for the mountain streams impeded by the dams in Armenia (Asatryan and Dallakyan, 2015, 2018), but also worldwide (Kamidis et al., 2021).

In total, the representatives of 53 taxa from 42 families were recorded during the field campaign that is by 5 families and 14 taxa more than in the 2012 (Asatryan and Dallakyan, 2021). Considering six sampling sites investigated in 2022 instead of two in 2012, this proves that hidden diversity of benthic macroinvertebrates is higher at the basin. The complete checklist for determining the reference/best available conditions has still not developed. At the same time, in 2022 we did not recorded species of Ceratopogonidae, Empididae and Pediciidae families from dipterans, species of Planorbidae family from gastropods, any Odonata species, Perlodidae species from stoneflies and species of Polycentropodidae from caddisflies. If in case of dipterans this can be explained by the features of life cycles of flies as many of them emerge in summer, lack of Odonata or Perlodidae species is possibly the consequence of the hydromorphological alteration of the riverbed. If to add missing taxa, the overall diversity of benthic macroinvertebrates during the last decade may reach 61 taxa of mostly genus level. However, for the purposes of improvement of hydrobiological monitoring further identification of species is still necessary as they improve also the reliability of the ecological status assessment results (Schmidt-Kloiber and Nijboer, 2004).

Structural changes in the community of benthic macroinvertebrates along the gradient of altitudes and habitats are also obvious. Trichoptera (caddisfly) had the highest diversity at family level (11) in sampling station Y1. Neither such high diversity nor the prevalence of caddisflies are common for one

**Table 4.** The structure of benthic macroinvertebrates (number of specimens) collected in the beginning of August of 2022; \* – taxon was not recorded in 2012.

Higher taxon	Family	Species	Station					
			Y1	Y2	Y3	Y4	Y5	Y6
Acariformes*	Hydrachnidae	Hydrachnidae gen. sp.	0	0	0	0	0	1
Amphipoda	Gammaridae	<i>Gammarus</i> sp.	0	10	0	10	0	0
	Niphargidae*	<i>Niphargus</i> sp.	1	1	0	0	0	0
Coleoptera	Dytiscidae	<i>Platambus lunulatus</i> (Fischer von Waldheim, 1829)	0	0	1	0	0	0
	Elmidae	Elmidae gen. sp.	100	110	0	4	9	4
	Hydraenidae*	<i>Hydraena</i> sp.	2	0	0	0	0	0
		<i>Ochtebius</i> sp.	0	0	0	0	1	0
Diptera	Athericidae	<i>Atherix</i> sp.	5	0	0	0	0	9
	Blephariceridae	<i>Blepharicera</i> sp.	8	0	0	7	14	0
	Chironomidae	Chironomidae gen. sp.	25	46	5	9	81	40
	Limoniidae	Limoniidae gen. sp.	0	0	0	0	0	0
	Muscidae*	Muscidae gen. sp.	0	1	0	5	6	0
	Pediciidae	<i>Dicranota</i> sp.	5	4	0	0	0	0
	Simuliidae	<i>Simulium</i> sp.	445	97	209	0	11	73
	Tabanidae	<i>Tabanus</i> sp.	0	2	0	0	0	2
	Tipulidae*	<i>Tipula rufina</i> Meigen, 1818	0	1	0	1	0	0
Ephemeroptera	Baetidae	<i>Baetis</i> sp.	40	237	23	35	176	118
	Caenidae	<i>Caenis</i> sp.	0	0	0	1	0	1
	Ephemerellidae	<i>Seratella ignita</i> Poda, 1761	22	8	75	21	8	23
		<i>Ecdyonurus</i> sp.	2	61	1	3	0	0
	Heptageniidae	<i>Electrogena pseudaffinis</i> * (Braasch, 1980)	9	2	0	0	13	3
		<i>Epeorus</i> sp.*	36	5	0	31	0	11
		<i>Rhitrogena decolorata</i> * Sinitshenkova, 1973	22	0	0	0	0	0
Gastropoda	Ancylidae	<i>Ancylus fluviatilis</i> O.F.Müller, 1774	4	4	0	2	8	3
	Lymnaeidae	<i>Galba truncatula</i> * (O.F. Müller, 1774)	0	0	0	2	0	0
		<i>Radix</i> sp.*	0	0	4	4	7	0
Hemiptera	Corixidae*	<i>Corixa</i> sp.	0	1	0	0	0	0
	Gerridae*	<i>Limnoporus rufoscutellatus</i> (Latreille, 1807)	0	0	1	0	0	0
	Notonectidae*	<i>Notonecta viridis</i> Delcourt, 1909	0	0	1	0	0	0

Higher taxon	Family	Species	Station						
			Y1	Y2	Y3	Y4	Y5	Y6	
Hirudinea	Erpobdellidae	<i>Erpobdella</i> sp.	0	0	6	0	0	1	
Isopoda	Asellidae	<i>Asellus aquaticus</i> (Linnaeus, 1758)	0	0	1	0	0	0	
Oligochaeta	Lumbricidae	<i>Eiseniella tetraedra</i> (Savigny, 1826)	0	0	0	12	0	0	
Plecoptera	Leuctridae	<i>Leuctra</i> sp.	0	2	0	0	1	0	
	Nemouridae*	<i>Protonemura</i> sp.	1	5	0	0	0	0	
	Perlidae	<i>Perla</i> sp.	8	10	1	0	0	0	
Trichoptera	Apataniidae	<i>Apatania subtilis</i> Martynov, 1909	2	0	0	0	0	0	
	Brachycentridae	<i>Micrasema bifoliatum</i> Martynov, 1925	28	0	0	0	0	0	
	Glossosomatidae	<i>Agapetus</i> sp.	0	0	1	0	0	0	
		<i>Glossosoma</i> sp.	9	87	3	4	3	3	
	Hydropsyche	<i>Hydropsyche</i> sp.	51	26	1	10	112	72	
	Hydroptilidae	<i>Hydroptila occulta</i> (Eaton, 1873)	0	0	0	0	0	8	
	Lepidostomatidae	<i>Dinarthrum</i> sp.	3	0	0	0	0	0	
		<i>Chaetopteryx</i> sp.	0	0	4	2	0	0	
	Limnephilidae	<i>Drusus caucasicus</i> Ulmer, 1907	9	0	0	0	0	0	
		<i>Halesus</i> sp.	10	0	0	0	0	0	
		<i>Limnephilus</i> sp.	0	2	0	0	0	0	
		<i>Wormaldia subnigra</i> McLachlan, 1865	0	0	0	2	0	0	
	Philopotamidae*	<i>Philopotamus montanus</i> (Donovan, 1813)	0	0	0	2	0	0	
	Psychomyiidae*	<i>Psychomyia pusilla schelkovnikovi</i> Martynov, 1925	0	0	0	1	0	26	
		<i>Lype</i> sp.	4	0	0	0	0	0	
	Rhyacophilidae	<i>Rhyacophila</i> sp.	8	35	0	10	0	1	
	Sericostomatidae	<i>Sericostoma grusiense</i> Martynov, 1913	2	4	0	0	0	0	
	Tricladida	Dugesiidae	<i>Dugesia</i> sp.	2	0	0	0	0	0
	<b>Number of taxa</b>			<b>28</b>	<b>24</b>	<b>16</b>	<b>22</b>	<b>14</b>	<b>18</b>
	<b>Number of families</b>			<b>24</b>	<b>22</b>	<b>15</b>	<b>19</b>	<b>14</b>	<b>17</b>
<b>% EPT</b>			<b>64</b>	<b>54</b>	<b>50</b>	<b>55</b>	<b>43</b>	<b>56</b>	
<b>% Diptera (without Blephariceridae)</b>			<b>14</b>	<b>25</b>	<b>13</b>	<b>14</b>	<b>21</b>	<b>22</b>	
<b>BMWP</b>			<b>165</b>	<b>136</b>	<b>79</b>	<b>119</b>	<b>90</b>	<b>85</b>	
<b>ASPT</b>			<b>6.3</b>	<b>5.9</b>	<b>5.6</b>	<b>5.7</b>	<b>6</b>	<b>5</b>	

particular river section in Armenia and mostly stands for the features of substratum and relatively low levels of pollution (Kalaninová et al., 2014).

Both the highest diversity of benthic macroinvertebrates (24 families) and the highest share of Ephemeroptera, Plecoptera and Trichoptera taxa (64%), which are the most sensitive groups of benthic macroinvertebrates, were also recorded at station Y1. The ecological status of the uppermost and less impacted site was excellent (see Table 4); it supports the assumption that the headwaters in the Yeghegis are the best available sites for getting data and making comparisons for other water bodies of the same type in the “Ararat BMA” (Asatryan and Dallakyan, 2021). Bearing in mind high sensitivity of MMI to the selection of the best available or reference conditions (Hering et al., 2006), the knowledge of current changes in Y1 becomes a milestone for further improvements of hydrobiological monitoring tools in the Ararat RBMA.

The decline in the diversity of benthic macroinvertebrates and in the ecological status downstream and particularly near the dams is manifesting about the impairment caused by the wastewater discharge from the settlements and hydromorphological alterations due to dam construction. In mountain regions of Armenia, dams for hydropowered plants are usually built in narrow gorges to fill the reservoirs without inundating large areas. Dams influence a river velocity for less than 100m distance upstream thereby causing some limited hydromorphological alteration of a riverbed and making effect on the microhabitat conditions for benthic macroinvertebrates. Such negative effects from the dams are well documented in other regions too (Quadroni et al., 2017).

Almost monthly studies of the hydrochemical status of the Yeghegis River conducted by the Hydrometeorology and monitoring center SNCO of the Ministry of Environment of RA comes to claim the results of hydrobiological investigation conducted in 2022 (Surface waters, 2022). The results of the state monitoring on water quality in the lower course of the Yeghegis River show the fluctuation between the third and fourth categories in five scale gradation, where the highest quality corresponds to the first category and the worst one – to the fifth category. The assessment relies on the national standards<sup>5</sup> and following the principle “one out all out”. This means that if at least one of the dozens hydrochemical parameters regularly measured within the state monitoring of surface waters’ quality does not meet the standard for the good quality throughout the year, the quality is not estimated as good. Usually this refers to nutrients and some microelements like molybdenum, which has geological origin in the water. However, in addition to such effects the structure of benthic macroinvertebrates also reflects well the hydromorphological degradation in the basin.

The results of the hierarchical cluster analysis of sampling sites by the structure of substratum (Fig. 1) claims that the grouping occurs based on the position towards SHPPs dams. The exclusion is the pair of sampling sites Y5 and Y6, where almost no differences in microhabitat conditions upstream and downstream the dam was found. Stations Y5 and Y6 are located few hundred meters upstream and downstream from the SHPP dam where no effect of hydromorphological alteration can be found. Also they are in a U-shape valley where the river gets the lower courses. In this segment of the river course there is an increased impact from an untreated municipal wastewater discharge responsible for the high cover area of *Cladophora* sp., less diversity of microhabitats and decrease in oligosaprobic species of benthic macroinvertebrates. Though Y2 was just a few hundred meters downstream from Y1, water abstraction for SHPP, situated between two sampling sites, affected the diversity and structure of benthic macroinvertebrates. The ecological status in Y2 lowers by one class according to the BMWP index and the share of EPT taxa decreases by 10% as compared to station Y1. Particularly, there was no any specimen of *Rhitrogena* mayflies and half of the caddisflies genera found in Y1 were not recorded here. The abundance of other sensitive taxa also decreased.

As it shown in Fig. 1, the sampling sites Y1 and Y2 have higher variance in the structure of substratum compared with the pair of stations Y2–Y4 located downstream from the dam. The largest differences in conditions were found at sampling site Y3 that was also reflected in the structure of benthic macroinvertebrates. For instance, such typical for lentic ecosystems species as *Platambus lunulatus*, *Limnoporus rufoscutellatus*, *Notonecta viridis*, *Asellus aquaticus* and *Agapetus* sp. were found only here. Also, the highest drop in the ecological status was recorded for station Y3 located a few hundred

<sup>5</sup> The RA Government Decree N75-N of 27 March 2011 "On the establishment of water quality standards for each water basin management area depending on the territory".

meters upstream from the SHPP dam. Despite the good ecological status and no necessity in specific measures on the ecosystem restoration, the overall score of BMWP index decreased by half compared with station Y1.

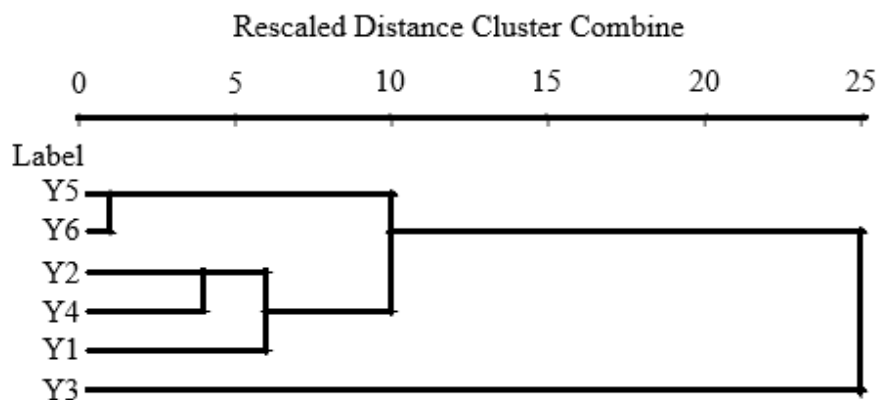
Thus, the changes in both the morphometric and hydrophysical parameters of the stream and in the structure of microhabitats has a major role in variance of benthic macroinvertebrates in relatively small mountain streams of the RBMA.

To estimate the rate of changes in the assemblage of the benthic macroinvertebrates between the stations, the similarity of taxonomic composition was analysed (Table 5). The results demonstrate the highest coincidence in the headwaters where wastewater discharge does not affect the ecosystem.

Obviously, the similarities are higher between the stations that are closer to each other spatially or by the structure of substratum. The exclusions are sampling sites Y2–Y4 and Y4–Y6, which are all impacted by the same hydromorphological stressor.

## Conclusion

A high level of coincidence in the taxonomic diversity of benthic macroinvertebrates of the Yeghegis River between the years 2012 and 2022 proves that during this decade no significant stressors-related changes have occurred. Hence, the multimetric index developed based on the baseline survey outcomes still can be used for the updated RBMP and the hydrobiological monitoring system can more intensely utilize its power in estimations of the ecological status. At the same time, the results prove that we still have some gaps in overall knowledge about the reference conditions for the “Ararat BMA”, which should be addressed with more detailed studies.



**Fig. 1.** The dendrogram of sampling sites derived through hierarchical cluster analysis of the substratum structure.

**Table 5.** The similarity of taxonomic composition of benthic macroinvertebrates according to the Sørensen–Dice index.

	Y1	Y2	Y3	Y4	Y5	Y6
Y1	1					
Y2	0.65	1				
Y3	0.36	0.39	1			
Y4	0.44	0.57	0.41	1		
Y5	0.48	0.58	0.45	0.56	1	
Y6	0.52	0.57	0.40	0.55	0.56	1

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