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# Studying macrozoobenthos community and assessing the ecological status of the Tandzut River for improving hydrobiological monitoring system in Armenia

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**Abstract.** The improvement of water management calls for action in the Republic of Armenia. Nowadays, the development of the hydrobiological monitoring approaches and procedures is the main goal. However, a lack of knowledge on the background conditions prevents further activities of reevaluating of the methods used for water monitoring in Armenia with the EU WFD principles. Following the results of baseline studies conducted in the Debed River system, it was concluded to investigate small tributaries in order to find the most relevant and the best available site in the drainage basin. The study aims to analyse the community of benthic macroinvertebrates of the Tandzut River. We suggest the Tandzut River as a relevant substitution for the recent best available site in the area due to the ecological status of the upper reaches of the Tandzut River, which is by one category higher than the recent best available site of the Pambak River system according to BMWP index.

**Keywords:** EU WFD, surface water, reference conditions, water management, monitoring system, Pambak River, Northern RBMA.

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## Introduction

The maintenance of the water quality of surface water bodies is of high importance both for the humanity and the ecosystems (Loucks and van Beek, 2017; William and Loucks, 2015). The EU Water Framework Directive<sup>1</sup> develops the principles and ap-

proaches for the establishment of proper water management systems in all Member States to achieve this goal. The Republic of Armenia accepted implementation of the state water monitoring system within the EU WFD. In particular, in 2011, the Government of the Republic of Armenia (RA) has adopted the decree no. 927-N, which strives to ensure better water governance in accordance with the EU WFD requirements. Following this decree, six river basin management areas (RBMA) have been established

<sup>1</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.

in the RA, and a number of baseline hydrobiological studies have been conducted there. However, the development of biological monitoring capacities in the RA is still one of the milestones for the establishment of proper national water monitoring system. The gap in the knowledge about river typology and reference conditions in Armenian rivers should be still filled to accomplish this goal (Asatryan and Dallakyan, 2021a). Currently, it is a very complicated issue for all the countries in the Caucasus since anthropogenic activity has been expanding widely over the last decades and the anthropogenic pressure from livestock grazing, irrigation systems, mines, and hydropower plants are clearly visible everywhere (Koronkevich et al., 2003). Therefore, the system of the best available sites instead of reference sites for each river basin has been established. However, in some river basins, the location of the best available sites is still under discussion and thus requires further improvement. At the same time, the best available or reference sites for hydrobiological monitoring routine should be accessible enough for regular visits and sampling<sup>2</sup>.

The basin of the Debed River belonging to the northern RBMA. The river is one of the major waterways of international importance in RA as the river flows further to Georgia. The baseline studies performed in the Pambak River subbasin showed no differences in the ecological status along all the studied parts (Asatryan and Dallakyan, 2021b). Nevertheless, after the establishment of monitoring sites in the Pambak River, the system of hydroelectric power plants (HPP's) has been expanded towards the tributaries that were early treated as relatively pristine sites. Particularly, when visiting the best available site at the Chichkan River (tributary of the Pambak River) in the late August of 2020, we have found only rare specimens of benthic macroinvertebrates. The latter means that the tributary has been affected by strong stress short before.

Although the proper river typology has not been developed in RA yet, we assume that the Tandzut River may become a relevant substitute for the recent best available sites in the Pambak River subbasin. Therefore, it was decided to compare the results for the Tandzut River with the last best available site of this river basin located in the Khndzorut (Shahumyan) River tributary. However, it should be stressed that this tributary is also experiencing pressure from HPP.

In general, the hydrobiological studies in the Tandzut River are lacking. The data on phytoplankton community of the lower reaches is available as the only BQE element (Mamyan, 2013; Mamyan et al., 2013). However, lower reaches flow through the Shahumyan village, so this area cannot be claimed as the

best available site. Moreover, benthic macroinvertebrates are the main BQE worldwide for the assessment of the ecological status of running surface water bodies due to their wide range of responses to different pollution types, this is also true for hydrobiological monitoring system in RA<sup>3,4,5</sup> (Birk et al., 2012; Johnson et al., 2006; Rosenberg and Resh, 1993; Springe et al., 2006).

We have undertaken the first hydrobiological study in the upper reaches of the river Tandzut. The obtained data on benthic macroinvertebrates of this river will serve as the basis for checking its relevance as a best available site for the Pambak River system. The perspective of this work is to justify applying these results for the entire northern RBMA and, particularly, for the Aghstev River system, because the sources of the latter locate very close to the Tandzut River.

The objectives of the study are:

1) to assess the ecological status of the Tandzut River based on the composition of benthic macroinvertebrates:

2) to compare the results with those obtained for the best available site in the nearby tributary, the Khndzorut River.

## Materials and methods

### *Study area and sampling sites*

The Tandzut River is a right-hand tributary of the Pambak River. Its source locates at the northern slopes of Pambak ridge; in RA, the river flows for 23 km at the Lori District. The river basin area covers 141 km<sup>2</sup>, mostly presented by the forests, so it serves as a recreation zone as well. The river feeds mainly by melting and rainwaters, the highest flow is observed in May. The average annual discharge is 2.24 m<sup>3</sup>/s (Mnatsakanyan and Tadevosyan, 2007), the average flow velocity in august 2020 – 0.8 m/s (pers. data). The Tandzut River confluences with the Khndzorut River in the Shahumyan village near Vanadzor city. Only three settlements are located in the drainage basin of the Tandzut River (Antarashen, Lermontovo, and Shahumyan) with a total population of ~3500. More than a half of population live along the river mouth area (Lori marz, 2020), thus not bringing a stable footprint in the upper and the middle reaches. The river and its banks is relatively pristine upstream Antarashen village due to a dense forest and V-shape valley at the upper reaches, so it seems to be a nice

<sup>2</sup> Rivers and lakes – typology, reference conditions and classification systems. Common implementation strategy for the Water Framework Directive. Guidance document no. 10.

<sup>3</sup> EPA 841-B-99-002, 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish. 2<sup>nd</sup> edition.

<sup>4</sup> EPA 841-B-99-002, 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish. 2<sup>nd</sup> edition.

<sup>5</sup> EPA 440-5-90-004, 1990. Biological criteria: national program guidance for surface waters.

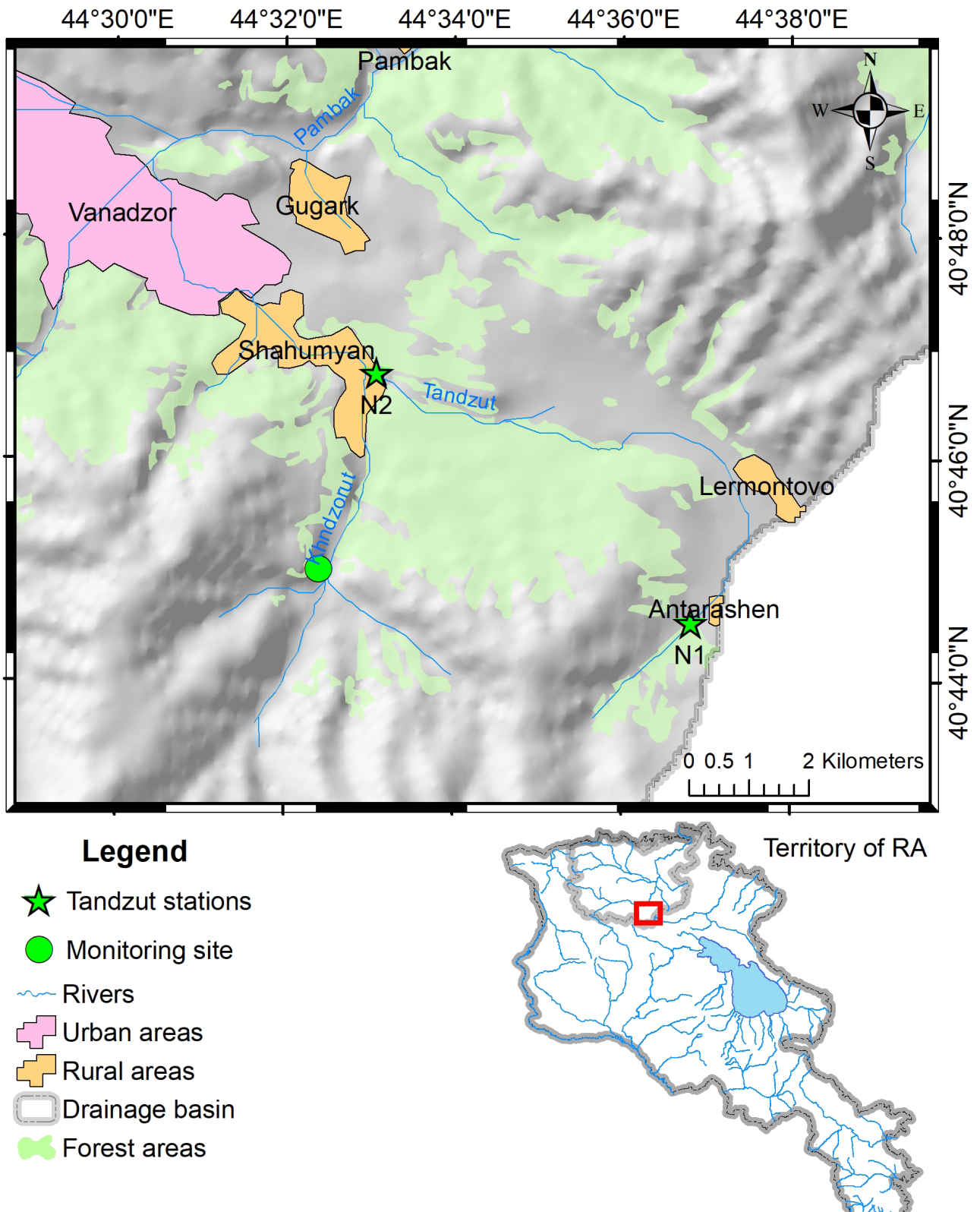


Fig. 1. Study area and sampling sites.

place for testing the hypothesis. Abandoned mining site is located downstream Lermontovo village, but some wastewater is yet being drained by the river from the mine.

Two sampling sites were analyzed in order to reveal the changes in the community of benthic macroinvertebrates along the course of the Tandzut River and to assess the ecological status of the river. The station no. 1 is located in the upper reaches (the width of river bed about 2 m), 0.5-km upstream Antarashen village, at altitude of 1977 m; the station no. 2, in the lower reaches (The width of river bed up to 7 m), in Shahumyan village, at altitude of 1477 m (Fig. 1). Due to a relatively short distance between the stations, the cumulative effects of all activities along the river course may be examined by an example of benthic macroinvertebrates at the station no. 2. The data on benthic macroinvertebrates collected by the authors during the summer of 2013 in the upper reaches of the Khndzorut River (a best available site for hydrobiological monitoring routine) were compared with the data obtained for the Tandzut River (Asatryan and Dallakyan, 2021b). It is worth to mention also that both rivers have almost similar hydro-morphological parameters at their upper reaches, as well as quite similar composition of the channel substrates.

### Sampling and processing of material

Sampling was performed in accordance with the EU standards<sup>6,7,8</sup> in late August 2020. This season for the hydrobiological monitoring was chosen considering seasonal fluctuations in water level and the features of the development of benthic macroinvertebrates in the mountain zones (Asatryan and Dallakyan, 2018). Five replicates of benthic macroinvertebrates were collected by Surber sampler (area of 0.09 m<sup>2</sup>; 500- $\mu$ m mesh size). The animals were taken from the sediments and immediately fixed in 96% ethanol.

Further sample processing and species determination were performed in the laboratory using the taxonomic keys (Kutikova and Starobogatov, 1977; Opredelitel'..., 2001; Eiseler, 2010; Waringer and Graf, 2011, 2013).

### Ecological status assessment

The ecological status of the Tandzut River was assessed by Biological Monitoring Working Party (BMWP) (Armitage et al., 1983) and complementary Average Score Per Taxon (ASPT) indices (Semenchenko and Razluckyi, 2010).

<sup>6</sup> EN ISO 10870:2012. Water quality – Guidelines for the selection of sampling methods and devices for benthic macroinvertebrates in fresh waters.

<sup>7</sup> EN 16150:2012. Water quality. Guidance on pro-rata multi-habitat sampling of benthic macro-invertebrates from wadeable rivers.

<sup>8</sup> Manual for the application of the AQEM system, 2002.

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

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

where  $T_i$  is a tolerance score;  $N_{taxa}$  is the number of taxa in the sample.

Tolerance scores and ecological status classes (Table 1) according to Wright et al. (1993), Leeds-Harrison et al. (1996), were used for the *BMWP* score calculation.

Unlike *BMWP* index, *ASPT* index (Table 2) is based on the calculation of average tolerance score at particular sampling site instead of the overall tolerance score.

The similarity of communities of benthic macroinvertebrates between two stations as well as between the station no. 1 and the data collected from the monitoring station at the Khndzorut River was calculated by the Sørensen-Dice index:

$$K = 2C/A + B,$$

where  $C$  is the number of taxa common for the both sites,  $A$  and  $B$  are the total number of taxa at each site (Sørensen, 1948).

**Table 1.** *BMWP* scores and the ecological status.

<i>BMWP</i> score	Ecological status
>150	Excellent
101–150	Very good
50–100	Good
25–49	Moderate
0–24	Poor

**Table 2.** *ASPT* scores and the ecological status.

<i>ASPT</i> score	Ecological status
5+	Excellent
4.5–4.9	Very good
4.1–4.4	Good
3.6–4.0	Moderate
3.1–3.5	Rather poor
2.1–3.0	Poor
0–2.0	Very poor

## Results and discussion

### **Structure of communities of benthic macroinvertebrates**

In total, 19 families of benthic macroinvertebrates have been recorded in the upper reaches of the Tandzut River (Table 3), which exceeds this number at the best available site at the Khndzorut River by 6 families. When comparing with our results obtained in 2012–2013 during the reference survey at the Debed River, the highest diversity has been found for any single station at the Pambak River. This allows to conclude that this station could be considered as the best available site for the entire Pambak River basin as well. At the same time, the representatives of 15 families have been recorded in the lower reaches of the Tandzut River, which also exceeds the species diversity at the best available regional site used for monitoring routine recently. Considering the stream width at the station no. 1 (~2 m) and the main components of the substratum (cobble and boulders), such diversity is quite high.

The larvae of mayflies of the family Baetidae dominated by abundance at both the upper and the lower reaches of the Tandzut River, while the non-biting midges (Chironomidae), in the upper reaches of the Khndzorut River. Baetidae mayflies are characterized by moderate sensitiveness to any pollution; however, they are more sensitive than non-biting midges.

At the same time, 16 taxa recorded at the upper reaches are characterized by tolerance score of  $\geq 5.0$ , which means that almost all recorded taxa there are reliable indicators of good state of the surface waters. Particularly, at the station no. 1, the larvae of stoneflies (Perlidae, Perlodidae, and Leuctridae), as well as larvae of mayflies of the family Heptageniidae have been recorded; all these taxa are rather sensitive to pollution. As an example, 12 taxa characterized by tolerance score of  $\geq 5.0$  have been recorded at the station no. 2, and only 9 taxa, at the Khndzorut station. Moreover, only one taxon (Plecoptera: Leuctridae) characterized by maximum tolerance score has been registered at the station no. 2, two taxa, at Khndzorut station. This comparison of pollution-sensitive taxa also justifies the difference in the ecological status between the two parts of the same river and the best available site at the Khndzorut River.

Flies (Diptera) are the most diverse group at all stations; this is common for similar altitudes and landscapes in RA (Asatryan and Dallakyan, 2021b). The share of the flies in the total diversity is 31% at the best available site of the Khndzorut River, in the upper reaches of the Tandzut River, about 38%, and in the lower reaches, 47%. At the same time, flies of Blephariceridae and Athericeridae families, which are rather pollution-sensitive, have been recorded in the Tandzut River basin, but not in the Khndzorut River.

When comparing the changes in the composition of benthic macroinvertebrates along the course of the Tandzut River, one has to note that mainly oligosaprobic and oxyphilic species are absent in the lower reaches. Particularly, caddisflies (Glossosomatidae), mayflies (Heptageniidae), and stoneflies (Perlidae, Perlodidae, and Nemouridae), all sensitive to organic pollution, are absent in the lower reaches. Empirically, the lower reaches are characterized by direct nutrient load into the Tandzut River with sewage from the households.

### **Ecological status**

According to *BMWP* index, the ecological status of the Tandzut River in the upper reaches is “very good”, which is higher by one category than that at the station no. 2 and at the best available site of the Khndzorut River. Moreover, when comparing these results with those obtained during the reference survey in the drainage basin (Asatryan and Dallakyan, 2021b), the ecological status of each station in the Pambak River system has been assessed for the first time as “very good” according to *BMWP* index.

Assessing the ecological status by *ASPT* index, it is obvious that the score decreases as “Station no. 1 → Station no. 2 → Khndzorut station”. Although the differences between the *ASPT* score for the station no. 2 and the Khndzorut River are rather small to conclude about the differences in their ecological status, but there is almost 1-point difference with the station no. 1. The latter supports the hypothesis about the possibility to substitute the best available site at the Khndzorut River by the station no. 1 in the Tandzut River, since the reference conditions in RA and proper river typology are not established yet.

Similarity of communities of benthic macroinvertebrates between the upper and the lower reaches of the Tandzut River is 0.65, between the best available site of the Khndzorut River and the station no 2, 0.57. The Sørensen-Dice index between the station no. 1 and the Khndzorut station is 0.56. Therefore, we argue that there are more similarities between the stations in the Tandzut River compared with the combinations between the stations at the Tandzut River and the Khndzorut River. Taking into consideration the presence of small operating HPP in the middle reaches of the Khndzorut River, such differences may be the result of seasonal water demand from the upper reaches for the generation of energy, since the altitude, landscape, slope, bottom sediments, and most of the physical parameters between the upper reaches of the Tandzut and the Khndzorut rivers are almost the same.

### **Conclusions**

The anthropogenic impact at the upper reaches of the Tandzut River is rather small comparing to that in the Khndzorut River; the sites at the Tandzut River

**Table 3.** Community structure of benthic macroinvertebrates of the Tandzut River. “–” family not found.

Higher classification	Family	Tolerance score	Number of specimens		
			Station no. 1	Station no. 2	Khndzorut station
Amphipoda	Gammaridae	6	–	1	1
Trichoptera	Rhyacophilidae	7	11	2	–
Trichoptera	Glossosomatidae	7	2	–	–
Trichoptera	Hydropsychidae	5	3	36	9
Trichoptera	Limnephilidae	7	7	17	30
Tricladida	Dugesiidae	–	–	–	1
Odonata	Aeshnidae	8	–	–	1
Diptera	Blephariceridae	7	–	13	–
Diptera	Chironomidae	2	1	3	606
Diptera	Dixidae	6	12	–	–
Diptera	Athericidae	7	9	2	–
Diptera	Tabanidae	3	–	–	6
Diptera	Tipulidae	5	1	1	4
Diptera	Pediciidae	5	10	1	–
Diptera	Psychodidae	2	–	2	–
Diptera	Limoniidae	5	2	–	–
Diptera	Simuliidae	5	41	3	116
Coleoptera	Elmidae	5	76	7	11
Coleoptera	Hydrophilidae	5	–	1	–
Plecoptera	Perlidae	10	1	–	–
Plecoptera	Nemouridae	7	45	–	–
Plecoptera	Perlodidae	10	13	–	38
Plecoptera	Leuctridae	10	23	13	–
Oligochaeta	Oligochaeta	1	3	–	–
Ephemeroptera	Baetidae	4	92	57	101
Ephemeroptera	Heptageniidae	10	69	–	19
<b>Total number of families</b>			<b>19</b>	<b>15</b>	<b>13</b>
<b>BMWP score</b>			<b>118</b>	<b>82</b>	<b>70</b>
<b>ASPT score</b>			<b>6.21</b>	<b>5.46</b>	<b>5.38</b>

may successfully substitute the latter in the hydrobiological monitoring routine as the best available site at the Pambak River system. However, specific substratum and morphological features (small tributaries) may provide valuable information about reference conditions only for this particular river type. In order to improve the state of hydrobiological monitoring system in the Republic of Armenia, following principal steps must be still realized:

1) establishing close cooperation with the partner Caucasus countries for the intercalibration procedures and adaptation of reference conditions potentially absent for the particular river types in certain country;

2) implementing the proper river typology in the Caucasus based on hydro-morphological, hydro-physical, and hydrochemical parameters;

3) further developing of multi-metric and multi-variate analyzing tools for reliable assessment of the ecological status of the surface water bodies and thus accepting relevant thresholds for high and good ecological statuses.

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