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THE ESTIMATION OF VARDENIS RIVER'S ECOLOGICAL STATE BY THE APPROACHES OF EU WATER FRAMEWORK DIRECTIVE

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The results of estimation of Vardenis river basin' water ecological state based on hydrobiological and hydromorphological studies has been presented. Study has been carried out by AQEM methodology which based on the norms of EU WFD. The results of river' water quality estimation by FBI, BBI, BMWP indices based on data of zoobenthos have been comparatively analyzed and the most reliable index for estimation of water quality based on multihabitat sampling method has been revealed.

The results have shown that the most reliable index from 3 implemented for the estimation of Vardenis river water quality is FBI. The scores of indices have shown that water quality of Vardenis river not lower than "good", at the same time all 3 indices have shown that the best quality is in the middle stream (FBI-1.4, BBI-9, BMWP-133), lower quality in the upper stream (FBI-4.8, BBI-7, BMWP-58) and the worst – in the downstream (FBI-5.35, BBI-4, BMWP-68). This is generally due to differences in anthropogenic impact size in different parts of river as a result of hydromorphological parameters.

Lake Sevan basin – Vardenis river – EU WFD – Zoobenthos – Water quality

Աշխատանքում ներկայացված են Վարդենիս գետի ավազանում իրականացված ջրակենսաբանական և ջրամորֆոլոգիական հետազոտությունների հիման վրա ջրի էկոլոգիական վիճակի գնահատման արդյունքները: Հետազոտություններն իրականացվել են ըստ AQEM-ի մեթոդաբանության, որը հիմնվում է ԵՄ ՋՇԴ նորմերի վրա: Զոոբենթոսի տվյալների հիման վրա FBI, BBI և BMWP ինդեքսներով իրականացված գետի ջրի որակի գնահատման արդյունքները ենթարկվել են համեմատական վերլուծության և բացահայտվել է մուլտիհաբիտատ նմուշառման հիման վրա ջրի որակի գնահատման համար առավել հավաստի ինդեքսը:

Արդյունքները ցույց են տալիս, որ կիրառված երեք ինդեքսներից Վարդենիս գետի ջրի որակի գնահատման համար առավել հավաստի է FBI ինդեքսը: Ինդեքսների արժեքները ցույց են տալիս, որ Վարդենիս գետի ջրի որակը ,լավ□ գնահատականից ցածր չէ, սակայն երեք ինդեքսներն էլ ցույց են տալիս, որ ջրի ամենաբարձր որակը միջին հոսանքի հատվածում է (FBI-1.4, BBI-9, BMWP-133), որին հաջորդում է վերին հոսանքի ջրի որակը (FBI-4.8, BBI-7, BMWP-58) և ամենացածրը՝ ստորին հոսանքում է (FBI-5.35, BBI-4, BMWP-68): Այսպիսի փոփոխությունների հիմնական պատճառը հիդրոմորֆոլոգիական պայմանների հետևանքով անթրոպոգեն ազդեցության չափի տարբերություններն են գետի տարբեր հատվածներում:

Սևանա լճի ավազան – Վարդենիս գետ – ԵՄ ՋՇԴ –Զոոբենթոս – Ջրի որակ

В работе представлены результаты оценки экологического состояния воды в бассейне рек. Варденис на основе проведенных гидробиологических и гидроморфологических исследований. Исследования были проведены по методике AQEM, которая создана на основе норм ВРД ЕС. Был проведен сравнительный анализ результатов оценки качества воды р. Варденис по индексам FBI, BBI и BMWP на основе данных по зоо- бентосу и выявлен самый достоверный индекс для оценки качества воды при мультиабитатном методе сбора материала.

Результаты показывают, что самым достоверным индексом из трех использованных является индекс FBI. Баллы индексов показывают, что качество воды реки Варденис не ниже "хорошего", при этом самое высокое качество воды было зарегистрировано в среднем течении (FBI-1.4, BBI-9, BMWP-133), несколько ниже – в верхнем течении (FBI-4.8, BBI-7, BMWP-58) и самое низкое – в нижнем течении (FBI-5.35, BBI-4, BMWP-68). Основная причина таких изменений заключается в различной степени антропогенного воздействия на разных участках реки, обусловленной гидроморфологическими условиями.

Бассейн озера Севан – Река Варденис – ВРД ЕС – Зообентос – Качество воды

Water Code of RA established in 2002 is largely based on the norms and approaches of EU Water Framework Directive (EU WFD (2000/60/EC)). Whereas the requirements of WFD are less integrated in the hydrobiological studies carried out in Armenia. Thus, an attempt to implement some requirements of WFD to hydrobiological studies was done in this work. The aim of this study is to assess the ecological state of Vardenis river based on the results of investigations according to WFD norms. Vardenis is one of the largest rivers of Lake Sevan basin. It starts from the north slopes of Vardenis range. The length of river is 28 km (4^{th} river by length in Lake Sevan basin), catchment basin is 116 km^2, density of hydrological net – 1.08 km/km^2 which is 1.4 times more than the average density of hydrological net in Sevan basin. Fall of stream is 1315 m, Stream gradient – 49.6 m/km. Vardenis floods in spring season due to mixed-type alimentation (56 % from snow melt, 31 % from groundwater, 13 % from rain). Average river discharge is 1.87 m^3/sec, maximal – 20 m^3/sec [1, 4]. Vardenis river is also significant, because it is spawning river for endemic fish species of Lake Sevan – Sevan ischkhan-trout and Sevan barbell [2].

Materials and methods. Hydrobionts are the primary and main components for estimation of ecological state of water ecosystems according to EU WFD. Particularly, the linking organism groups are benthic macroinvertebrates, benthic diatoms, ichthyofauna and macrophytes [6]. Huge amount of studies shows, that benthic macroinvertebrates is the most suitable assemblage for estimation of water ecological state in the small mountainous rivers according to requirements of WFD [5, 7-9, 11, 12]. Based on this, the complex hydrobiological and hydromorphological field studies in Vardenis river basin were carried out in October of 2013. The month has been chosen as a most appropriate for hydrobiological studies according to WFD requirements, because it is followed by the low water phase of river Vardenis, which is the most suitable period for monitoring. The study has been carried out in 4 stations. I station is in the upstream of the river (39^0 59′ 20″ N, $45^0$26′52″E). It is in the 2680 m above sea level (a.s.l). Dominant biotopes here are mesolithal (>6cm to 20cm) – 45% and macrolithal (>20cm to 40cm) – 35%. II station – before small HPP ($40^0$05′28″N, $45^0$27′43″E) is located in 2220 m a.s.l., dominant biotops are megalithal (>40cm) – 40 % and macrolithal – 35 %: III station – 0.5km above Vardenik village ($40^0$07′24″N, $45^0$27′03″E) is located in 2000m a.s.l. Dominant biotops are mesolithal – 50% and megalithal – 25%: Besides stone biotopes, sampling in this station was carried out from inorganic silt and clay as well. IV station – downstream (40^0 09′41″N, 45^0 25′47″E) is located in 1918 m a.s.l. Dominant biotopes are mesolithal – 40 %, and macrolithal – 25 %. Besides stone biotopes, sampling in this station has been carried out from sand-sludge (10%) and submerged macrophytes (5 %) as well. Registration of hydromorphological data, sampling of benthic macroinvertebrates and following laboratory processing of materials have been carried out by the methods of AQEM consortium [10]. Estimation of water quality has been done by the indices FBI, BBI and BMWP [3]. Spatial processing and analyze of sampled data were carried out by ArcMap 10.1 software.

Results and Discussion. Due to study, the ecological state of water in different parts of Vardenis river has been estimated. All implemented indices have shown that the best conditions were in the II then in the III station (tab. 1). Mentioned 2 stations are in the middle stream of the river, which allow us to make a conclusion, that middle stream is the most pristine.

Table 1. Water quality in different stations of Vardenis river

Biological index	Stations			
	I	II	III	IV
Water quality by BBI index (value of index)	good (7)	high (9)	good (8)	bad (4)
Water quality by FBI index (value of index)	good (4.81)	excellent (1.4)	excellent (1.94)	good (5.35)
Water quality by BMWP index (value of index)	good (58)	very good (133)	very good (103)	good (68)
Water quality by BMWP index, sole individuals doesn't calculated (value of index)	good (58)	very good (122)	good (81)	not high (48)
EPT (%)	22	97	86	34

The results of different water quality estimation indices for I and IV stations are contradictory. Values of FBI and BBI indices have shown, that water quality of I station is better. Although, BMWP score has shown that water quality of both stations are "good", but the value of BMWP score in station IV has been higher than in station I. The reason of such contradictory lies in the multihabitat sampling method and theoretical approaches of calculation of different indices. On the assumption of multihabitat sampling method, the number of zoobenthic families in the IV station has been more than in station I by 5 families (tab. 2). Thus, the score of BMWP index, which based on the number of revealed families of zoobenthos is not reliable for stations I and IV.

Table 2. The structure of benthic fauna of Vardenis river

	Taxon name		Stations			
Group	Order	Family	I	II	III	IV
Insecta	Diptera	Tipulidae	-	-	-	+
Insecta	Diptera	Simuliidae	-	+	-	+
Insecta	Trichoptera	Sericostomatidae	-	+	+	-
Insecta	Trichoptera	Rhyacophilidae	+	+	+	-
Insecta	Diptera	Psychodidae	-	+	+	-
Mollusca	Gastropoda	Planorbidae	-	+	+	+
Insecta	Plecoptera	Perlidae	-	+	+	-
Insecta	Diptera	Pedicidae	+	+	-	-
Mollusca	Gastropoda	Lymnaeidae	-	-	-	+
Insecta	Trichoptera	Limnephilidae	-	+	-	-
Insecta	Ephemeroptera	Leptophlebiidae	-	+	-	-
Insecta	Trichoptera	Hydropsychidae	-	+	+	+
Insecta	Coleoptera	Hydraenidae	+	+	+	-
Insecta	Odonata	Gomphidae	-	+	-	-
Hirudinea	Rhynchobdellidae	Glossiphoniidae	-	-	+	-
Crustacea	Amphipoda	Gammaridae	-	+	+	+
Hirudinea	Arhynchobdellida	Erpobdellidae	+	-	-	+
Insecta	Coleoptera	Dytiscidae	-	-	+	-
Platyhelminthes	Turbellaria	Dugesiidae	-	+	+	+
Insecta	Diptera	Chironomidae	+	+	+	+
Insecta	Plecoptera	Capniidae	+	+	+	-
Insecta	Ephemeroptera	Caenidae	-	-	-	+
Insecta	Trichoptera	Brachycentridae	+	+	+	+
Insecta	Ephemeroptera	Baetidae	+	+	+	+
Insecta	Diptera	Athericidae	-	+	-	-
Insecta	Coleoptera	Elmidae	-	+	+	+
Insecta	Ephemeroptera	Heptagenidae	+	+	+	+
Insecta	Diptera	Limnophilinae	-	+	+	+
Insecta	Plecoptera	Nemouridae	-	+	+	-
Insecta	Plecoptera	Perlodidae	+	+	+	-
Total number of family			10	24	21	15

In case of using BBI index the sole individuals have primarily eliminated, thus water quality of I station has been estimated as "good" and in station IV – as "bad", which has also not reliable result. FBI is the most integral index from mentioned due to its methodology of score calculation. So, the most reliable result for multihabitat sampling method has been gained when FBI index were used. Thus, we recommend FBI

in-dex for the estimation of Vardenis river water quality and future using of these results for river basin ecological zoning.

The percent of Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa in all taxonomical diversity of each station has been calculated to check the validity of gained results estimated by indices, because these 3 groups of zoobenthos are more sensitive to pollution. The results have shown that in both stations of middle stream representatives of EPT taxa were absolutely dominant. On the other hand, their percent in taxonomical diversity of I and IV station were low than 35 %. Furthermore, although their part in the taxonomical diversity of station IV is a little bit higher than in station I, but it is due to high number of Baetidae family representatives, which are resistant to the pollution.

The model of Vardenis river basin slope gradient has been created by using the slope tool of GIS, which allow us to recognize the reasons of such fluctuations in water quality between different parts of the river. The results of hydromorphological parameters recorded within field study and gained from laboratory processing have shown that the upper stream of the river coincides with the trough valley, which is the main area for pasture and meadows in the basin of Vardenis river. Due to this, hydroecosystem in this area carries additional anthropogenic and natural organic pressure. After trough valley Vardenis river flows into V-shape valley, which become a canyon in some parts and anthropogenic pressure in this area reach a minimum value. Due to high stream gradient and flow velocity water in this part self-purifies intensively. Thus, in the middle stream, where anthropogenic pressure is minimal because of relief, water quality is strongly improves. Adjacent to Vardenik village perennial gardens and arable, which have an influence on water quality of Vardenis river, spreads along river banks, and after village sewages inflow into the river as well, which strengthen the organic and nutrient enrichment in the downstream course of the river.

Thus, due to hydromorphological features and as a result of different strength of anthropogenic pressure in different parts of Vardenis river, the basin can be conditionally divided into 3 different zones. I zone coincides with the trough valley in upper stream, where water quality is lower than in the middle stream due to impact of Livestock and meadows. The more pristine part of river is the II zone, which coincides with the middle stream of Vardenis river. This zone starts from the edge of trough valley and spreads to the upper boundary of settlement system. There is no obvious anthropogenic pressure on hydroecosystem due to hydromorphological conditions. III zone, which coincides with the downstream of the river, is the most vulnerable, because it is influences by the sewages and agricultural wastewaters of Vardenik village. Due to this, water quality of some parts of Vardenis river downstream can be lower than the necessary "good" quality required by WFD. The results of investigations and estimation of water quality have shown that in general water quality of Vardenis river appropriate for spawning of endemic fishes as well.

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