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The Growth Rates of Hydrobionts in the Argichi and Vardenis Rivers under the Conditions of the Impact of Small Hydropower Plants

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Abstract: *The aim of the present study was to assess the impact of the small hydropower plants on the growth of aquatic organisms in the Argichi and Vardenis rivers which are situated in the eastern part of Armenia. Observations, measurements and samplings were done in the sites situated in the upstream and downstream from the small hydropower plants located on the rivers in October-December 2013, January, February and May 2014. The hydrobiological studies showed that a decrease in the quantitative and qualitative parameters of benthic macroinvertebrates, a reduction in the quantity and species composition of fishes were observed in the Argichi river according to the observation sites situated in the upstream and downstream from the small hydropower plant (SHP) which was due to the impact of the SHP. During the investigation period, the quantitative and qualitative parameters of benthic macroinvertebrates in the upstream from the Vardenis river SHP were the following: the quantity ranged from 311 to 2616 individuum/m^2; the biomass ranged from 380 to 5337 mg/m^2; the number of species ranged from 17 to 29. Only fish species hooked from this site was Salmo trutta fario (Linnaeus 1758) the quantity of which ranged from 0 to 3 specimen/site. In the site situated in the downstream from the Vardenis river SHP, the ecosystem was destroyed due to the intake of almost all the quantity of the water by the SHP. The operation of the SHPs also blocked the movement of the Lake Sevan endemic fish species to the sources of the rivers which are the most favorable places for their spawning.*

Keywords: *Armenia, river ecosystem, hydrobionts, small hydropower plant.*

1. Introduction

The increasing demand of energy in many countries, especially in developing countries has led to the acceleration of energetic sphere development rate. In recent years, the number of small hydropower plants has increased sharply and has a tendency to increase for producing ecologically clean energy in energetic sphere [1, 2].

Nowadays, the study of the impact of small hydropower plants on aquatic ecosystems is urgent and has a scientific and practical interest as the latters' increasing number has become a serious threat to aquatic biocenoses and may cause significant changes in their qualitative and quantitative parameters.

Water intake needed for small hydropower plants decreasing the natural flow of rivers affects their hydrological, physicochemical and hydrobiological parameters [3, 4]. These energetic constructions may not only kill fishes but also block fish migration in a riverbed affecting their natural reproduction negatively [4].

A similar situation is observed in the Lake Sevan basin where the spawning rivers of the Lake Sevan endemic fish species are influenced by the small hydropower plants located on them which can lead to changes in the water hydrological, physicochemical and hydrobiological parameters and the reproduction conditions of

the endemic fish species. The spawning of Lake Sevan endemic fish species such as Khramicarp – *Varicorhinus capoeta sevangi*, Barbel – *Barbus goktschaicus* and Trout – *Salmo ischchan*, the 2 races of which – *Salmo ischchan typicus Kessler* and *Salmo ischchan Danilewskii Jakovlev* have disappeared completely, and the other 2 races – *Salmo ischchan gegarkuni Kessler* and *Salmo ischchan aestivalis Fortunatov* are endangered by various anthropogenic factors, occurs in the sources of the rivers flowing into Lake Sevan [5].

The aim of the present study was to assess the impact of the small hydropower plants on the growth of aquatic organisms in the Argichi and Vardenis rivers which are situated in the eastern part of Armenia.

2. Materials and Methods

The objects of the study were the Argichi and Vardenis rivers. Hydrological (river velocity, discharge, water level) and hydrobiological (macrozoobenthos and fish) studies were implemented in the sites situated in the upstream and downstream from the small hydropower plants located on the rivers in October-December 2013, January, February and May 2014.

River water level was measured by a water level meter. The height of the water level was recorded at the centre of the river width.

For the calculation of the river velocity in the investigation sites, the length of the investigation sites of the rivers was measured. A bobber was vented from the selected point of the rivers, and a stopwatch was started. The watch was stopped after the bobber passed the selected distance. The river velocity was determined by dividing the selected distance by the time recorded on the watch.

River discharge in the investigated sites was measured by the following formula:

$$Q = \omega \times V \quad (1),$$

where Q is the river discharge, ω is the cross-sectional area of the river at the point of flow measurement, V is the velocity at which the water travels across that section.

The cross-sectional area of the river was calculated by multiplying the water level by the river width. As only one measurement of the water level was taken, therefore an approximation in calculating the river cross section was considered.

For the study of macrozoobenthos community, the samples were taken from the different biotopes of benthic fauna by a device of a surface of $0.09m^2$. The animals were moved in cans and preserved with 4% formaldehyde solution. The further processing of the samples was executed under laboratory conditions. The animals were separated from the substrate and sorted into different taxonomic groups [6, 7]. The identification of taxonomic groups, and the determination of quantitative parameters were done by the standard methods accepted in hydrobiology [8-10].

Fishes were caught by a hunting net and fixed with 4% formaldehyde solution for the identification of fish species under laboratory conditions [11, 12].

3. Results and Discussion

Hydrological studies in Winter months showed that the Argichi river site situated in the upstream from the small hydropower plant (SHP) was frozen, but the river site situated in the downstream from the SHP wasn't frozen because the non-frozen waters of the middle and lower layers of the river water passed to this site through the SHP. In the other months of the investigation, according to the observation sites situated in the upstream and downstream from the SHP, the Argichi river discharge and water level decreased, and the river velocity increased, because the Argichi is a lowland river, and the fish passage system of the SHP has incline as a result of which the flow velocity in the observation site situated in the downstream from the SHP increased (Tab. I). Due to the intake of almost all the quantity of the water by the SHP, the Vardenis river in the observation site situated in the downstream from the SHP was characterized by the absence of the flow (Tab. II).

TABLE I: The Hydrological Regime of the Argichi River

Year	Month	Argichi river					
		Upstream from SHP			Downstream from SHP		
		River velocity (m/s)	River discharge (m^3/s)	Water level (cm)	River velocity (m/s)	River discharge (m^3/s)	Water level (cm)
2013	October	0.53	3.17	33	0.67	2.18	25
	November	0.52	2.98	32	0.65	1.69	20
	December	nil	nil	nil	0.34	0.41	12
2014	January	nil	nil	nil	0.33	0.36	11
	February	nil	nil	nil	0.34	0.44	13
	May	0.70	15.40	88	1.08	11.34	70

TABLE II: The Hydrological Regime of the Vardenis River

Year	Month	Vardenis river					
		Upstream from SHP			Downstream from SHP		
		River velocity (m/s)	River discharge (m^3/s)	Water level (cm)	River velocity (m/s)	River discharge (m^3/s)	Water level (cm)
2013	October	1.12	2.16	35	nil	nil	nil
	November	1.04	1.94	34	nil	nil	nil
	December	0.91	1.60	32	nil	nil	nil
2014	January	0.80	1.32	30	nil	nil	nil
	February	0.83	1.46	32	nil	nil	nil
	May	1.53	6.43	60	nil	nil	nil

Based on the t-test, the observation sites situated in the upstream and downstream from the Argichi river SHP were significantly different ($p < 0.05$) from each other according to the macrozoobenthos quantitative parameters and the recorded quantity of fishes.

Hydrobiological studies in Fall months showed that the quantitative and qualitative parameters of macrozoobenthos in the Argichi river decreased according to the observation sites situated in the upstream and downstream from the SHP (Figs 1-3). This was a newly built SHP, and during the observations in October, it had not yet been operating and was tested. The SHP construction works probably had affected the water quality causing water contamination with solid particles, a decrease in photosynthetic activity, the destruction of aquatic plants and other unfavorable conditions for the growth of hydrobionts as a result of which the ecosystem appeared in this site had not yet obtained stability.

In Winter months, animals, that are typical for low-flowing and silty biotopes, were included in the macrozoobenthos composition of the Argichi river site situated in the downstream from the SHP.

In May, according to the observation sites situated in the upstream and downstream from the Argichi river SHP, the quantitative parameters of macrozoobenthos decreased, and the qualitative parameters increased (Figs 1-3). These changes in the quantitative and qualitative parameters of benthic macroinvertebrates are explained by the bottom substrate composition formed by the operation of the SHP.

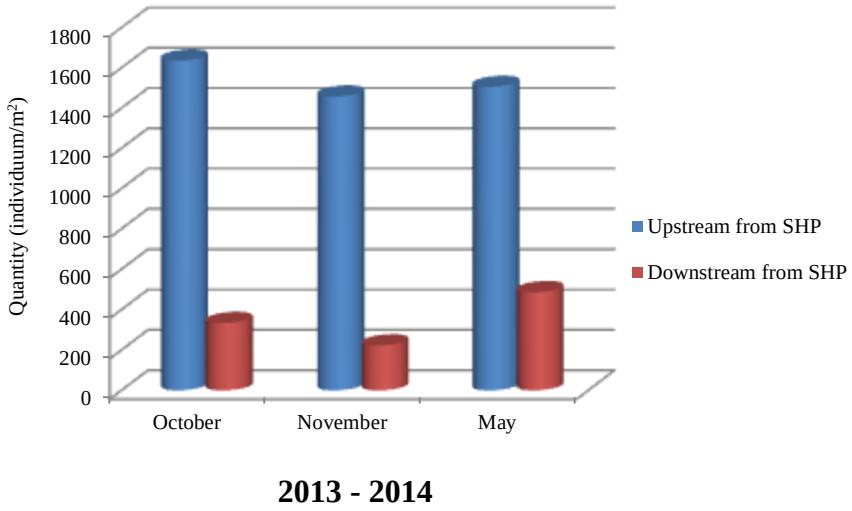

Fig. 1: The quantity of macrozoobenthos in the upstream and downstream from the Argichi river SHP.

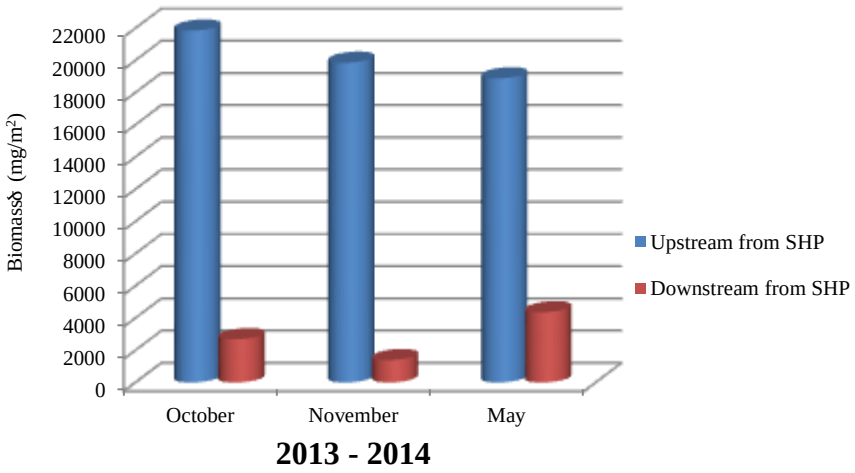

Fig. 2: The biomass of macrozoobenthos in the upstream and downstream from the Argichi river SHP.

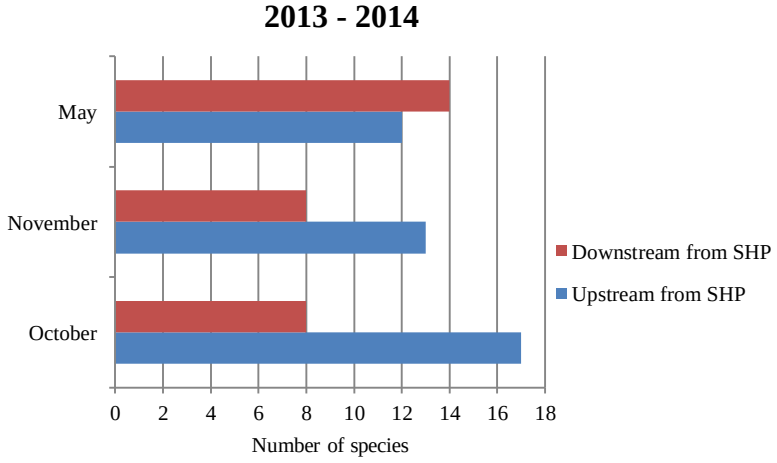

Fig. 3: The number of macrozoobenthos species in the upstream and downstream from the Argichi river SHP.

During the investigation period, the fish species Khramicarp – *Varicorhinus capoeta sevangi* and Barbel – *Barbus goktschaicus* were hooked from the Argichi river site situated in the upstream from the SHP, and the only fish species registered in the site situated in the downstream from the SHP was Barbel – *Barbus goktschaicus,* the quantity of which, compared to the quantity of the same fish species hooked from the site situated in the upstream from the SHP, was low (Tab. III). According to the observation sites situated in the upstream and downstream from the SHP, a reduction in the quantity and species composition of fishes may have been conditioned by the impact of the construction works of the newly built SHP, a change in hydrological regime as well as a significant reduction in the biomass of benthic macroinvertebrates in the new biotope formed in the river site situated in the downstream from the SHP (Fig. 2, Tab. I). These organisms are the main ingredient of the feed of the fish species Barbel – *Barbus goktschaicus.*

The races *Salmo ischchan gegarkuni Kessler* and *Salmo ischchan aestivalis Fortunatov* of the species *Salmo ischchan* spawn in the Lake Sevan tributaries where the sources are considered as the most favorable places for spawning. *Salmo ischchan gegarkuni Kessler* spawns in Fall and Winter, and *Salmo ischchan aestivalis Fortunatov* spawns in Spring. In the spawning period of *Salmo ischchan gegarkuni Kessler* and *Salmo ischchan aestivalis Fortunatov,* no one specimen of these fishes was registered in the studied observation sites of the Argichi river. This allows us to conclude that the SHP located on the river prevented the movement of *Salmo ischchan gegarkuni Kessler* and *Salmo ischchan aestivalis Fortunatov* to the source of the river affecting their natural reproduction negatively.

TABLE III: The Species and Quantity (specimen/site) of Fishes Registered in the Upstream and Downstream from the Argichi River SHP

Fish species	Quantity											
	October (2013)		November (2013)		December (2013)		January (2014)		February (2014)		May (2014)	
	Upstream from SHP	Downstream from SHP	Upstream from SHP	Downstream from SHP	Upstream from SHP	Downstream from SHP	Upstream from SHP	Downstream from SHP	Upstream from SHP	Downstream from SHP	Upstream from SHP	Downstream from SHP
Varicorhinus capoeta sevangi	3	0	4	0	nil	0	nil	0	nil	0	4	0
Barbus goktschaicus	14	8	12	8	nil	3	nil	2	nil	2	15	10

During the investigation period, the quantitative and qualitative parameters of benthic macroinvertebrates in the upstream from the Vardenis river SHP were the following: the quantity ranged from 311 to 2616 individuum/m^2; the biomass ranged from 380 to 5337 mg/m^2; the number of species ranged from 17 to 29. Only fish species hooked from this site was *Salmo trutta fario* (Linnaeus 1758) the quantity of which ranged from 0 to 3 specimen/site. In the Vardenis river site situated in the downstream from the SHP, the aquatic ecosystem within a distance of a few kilometers was destroyed due the intake of almost all the quantity of the water by the SHP, and the fish passage system of the SHP had formal nature.

4. Conclusions

The operation of the SHP located on the Argichi river affected the hydroecosystem causing changes in the qualitative and quantitative composition of hydrobionts: in the new biotope formed by the impact of the SHP, a decrease in the quantitative and qualitative parameters of benthic macroinvertebrates, a reduction in the quantity and species composition of fishes were observed. In the Vardenis river site situated in the downstream from the SHP, the ecosystem was destroyed due the intake of almost all the quantity of the water by the SHP. The operation of the SHPs also affected the natural reproduction of the Lake Sevan endemic fish species preventing their movement to the sources of the rivers which are the most favorable places for their spawning.

5. Acknowledgements

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