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PHYSICOCHEMICAL WATER QUALITY INDICATORS IN THE NERETVA RIVER BASIN (B&H) WITH REFERENCE TO ECOLOGICAL CONDITIONS FOR ENDEMIC SALMONIDS

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Abstract

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Due to its natural features, the Neretva River has been interesting throughout its stream for the construction of energy facilities, as well as its tributaries Rama, Trebišnica, Tihaljina, Lištica. Jablanica (1955), HPP Rama (1968), CHE Čapljina (1979), HPP Salakovac (1981), HPP Grabovica (1982), HPP Mostar (1987), HPP Peć Mlini, HPP Mostarsko blato have been built on the Neretva River and its tributaries. HPP. The aim of this paper is to determine the state of chemical and physical parameters of water in reservoirs and streams, as well as the parameters of the aquatic environment in which endemic salmonids previously lived and the possibility of revitalization of these watercourses. The ecological conditions of the Neretva reservoirs for the life of Neretva-endemic fish and the similarity to the conditions in the natural course of Neretva before the construction of the dam were examined. The research was conducted during 2017 and 2018 at several locations in the Neretva river basin (reservoirs and streams).

Key words: water quality, Neretva river basin, ecological conditions.

Introduction

The Neretva River is the longest and richest river in the Dinaric karst (Slišković, 2014). Because of these features, it has been preferred for the construction of energy facilities throughout. The construction of concrete dams on Neretva and the formation of artificial reservoirs for the production of electricity began in February 1955 with the construction of the first and largest hydropower plant, HPP Jablanica. After the construction of HPP Jablanica, the construction of other hydropower plants on the Neretva River began – HPP Rama (1968), HPP Čapljina (1979), HPP Salakovac (1981), HPP Grabovica (1982), HPP Mostar (1987) and HPP Mostarsko blato (2010).

The construction of artificial reservoirs flooded a significant part of the Neretva riverbed. Before the formation of water reservoirs, the fauna of fish was, both in number and diversity of species, significantly different from today›s fauna in lakes, the rest of the river and its tributaries (Aganović et al., 1966). The reason for this is the fact that water reservoirs change biotic and abiotic living conditions in water. As a result, a good part of the indigenous aquatic fauna was destroyed, while a part was significantly reduced. In addition, completely new ecological conditions have been created, that is, typical salmonid (trout) ecosystems have been transformed into cyprinid (carp) ecosystems (Aganović et al., 1966).

Reservoirs built on Neretva provide living conditions for fish and other aquatic organisms and plants. However, the conditions in them differ significantly from the ecological conditions that Neretva and its tributaries had before the construction of the accumulation lakes. Physicochemical characteristics of water have changed significantly, and as a consequence of this change, there have been major changes in fish populations, certainly to the detriment of endemic and indigenous species (Pavličević et al., 2012).

In the middle part of the Neretva basin, however, it is still not so pronounced, while for the lower course, there are scientific data on indications of pollution (Štambuk Giljanović, Pejaković, 1998). The source of pollution in the investigated part of the stream (locations of today›s hydro-accumulations) is Konjic wastewater. A slight impact of the organic load of the water of Lake Jablanica was registered in the research of Zupković et al. (1989). A relatively large load of various pollutants is felt on the health status of fish in these ecosystems because such water basins are at the same time a type of collector in which sedimentation and long-term retention of pollution takes place. Slowed or disabled water flow increases these effects secondarily, as this phenomenon significantly reduces the possibility of self-purification.

One of the possible sources of pollution are cages used for fish farming, because all unused food and waste end up in the

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ecosystem of water accumulation. Also, the erosive (alluvial) material of the catchment area brings with it a certain amount of pollutants. Agricultural areas are sources of organic and inorganic loads for water, and thus ichthyofauna. It so happens that, in addition to reducing the depth of the lake (due to the accumulation of sediments), the water quality takes on a different character (Škrijelj, Ćeman, 1993).

Daily and continuous water consumption in reservoirs very often leads to sudden fluctuations in water levels. According to the continuity and intensity of consumption, water level oscillations can be classified into two categories: regular (technological – due to the operation of power plants) and occasional (excessive). If we add to the mentioned anthropogenic influences the effects of sport fishing and poaching, we come to the conclusion that the ichthyofauna of Neretva is endangered in many ways and that it is, practically, in a constant «struggle for survival.»

The waters of the Neretva basin in Bosnia and Herzegovina belong to the Adriatic basin. The inflow of water is more significant compared to the other parts of the Adriatic basin. The rivers of the Adriatic basin are short flowing and isolated, often connected by underground flow systems, and are characterized by river valleys and karst canyons, large karst fields with sinkholes in the interior, and brackish estuaries. The banks of the rivers of the Adriatic basin are shallower in places, and the bottoms of the riverbeds are soft and overgrown with lush aquatic vegetation. In karst fields, sinkholes often spring at one end and sink at the other end of the field.

The rivers of the Adriatic basin are characterized by complex hydrology; in autumn and spring, they are richer in water, while in summer, some can dry out completely. The ecological feature of these waters is small temperature fluctuations in the upper streams. It is especially interesting that trout species come here at very low altitudes, often even to the mouth of the sea. One of the very important features of the Dinaric karst watercourse is the complete summer drainage of the watercourse. However, in groundwater systems, water is retained and does not dry out, thus allowing fish to survive. Species that inhabit such habitats have special physiological adaptations that allow them to stay longer underground in conditions of food shortage and low concentration of dissolved oxygen (Glamuzina et al., 2010).

The area of the Neretva river basin is defined by the geological composition of the terrain and amounts to about 7,948 km^2. The total length of the permanent surface river network in the Neretva basin, with streams that have a stable hydrological function, is about 1,948 km.

The Neretva River with its system of tributaries and flowing lakes forms the backbone of the Adriatic basin. In the upper part, it receives the right tributaries Jasenica, Rakitnica, Trešanica, Kraljušnica, Neretvica, and Rama, while on the left side, Šištica and Biščica flow into it. In the middle part, from Jablanica, it changes its course and flows to the south, where Doljanka and Drežanka flow on the right side and the Prenjska river flows on the left. In the lower course, from Mostar, it emerges from the canyon and forms a valley. In that part, on the right side, it receives the waters of Radobolja, Lištica, and Ugrovača, which come via Mostarsko blato and Jasenica, and, downstream from Čapljina, the river Trebižet. On the left, it receives the waters of Buna, Bregava, and Krupa.

The Water Framework Directive 2000/60/EC (WFD) requires that surface water bodies in a river basin district be classified into one of the following categories: rivers, lakes, transitional waters, and coastal waters, and then as artificial or heavily modified surface water bodies.

According to the Law on Waters of the Federation of B&H («Official Journal of the F B&H,» No. 70/06) (hereinafter The Law), surface waters, according to their importance for water management, are classified into waters of category I and waters of category II.

The waters of the first category in the water area of the Adriatic Sea in the research area are: the watercourses Neretva, Trebišnjica (regulated part of the watercourse), Matica (Vrljika), Tihaljina, Mlada, Trebižat, Bregava, Krupa, Lištica (downstream from Široki Brijeg), Rama, and accumulation Rama, as well as the natural lakes and wetlands Boračko Lake, Blidinje Lake, and Hutovo Blato. All remaining waters are waters of second category.

The goals of water management are: to achieve good status or good ecological potential of surface and groundwater, that is, water and water-related ecosystems; reduction of damages caused by various harmful effects of water; ensuring the necessary quantities of water of appropriate quality for various purposes; and encouraging sustainable use of water, taking into account the long-term protection of available sources and their quality.

In order to achieve and maintain good status or good ecological potential, the characteristics of water body types are determined. Surface water bodies in a river basin district are classified into one of the following types: rivers, lakes, transitional waters, and coastal sea waters, or as artificial or heavily modified water bodies. In each category, the surface water in the river basin district is classified into types in accordance with the methodology established by by-laws. For artificial or heavily modified water bodies, the same methodology is applied as for the types of surface water that most closely match the description of that artificial or heavily modified water body.

The ecological status of a surface water body is classified as high, good, moderate, weak, or poor. The classification is performed according to the reference conditions determined by the by-laws referred to in Article 43, paragraph 1, item 2 of the Act.

The chemical status of a surface water body is classified as good or bad. The classification is performed according to the reference conditions determined by the by-laws referred to in Article 43, paragraph 1, item 2 of the Act.

For artificial and heavily modified surface water bodies, the criteria for determining the ecological status of surface water bodies referred to in Article 32, paragraph 3 of the Act shall be applied, taking the one that is most similar to them. In the classification of ecological status, the characteristics for high ecological status will be determined as conditions for maximum ecological potential.

One of the main tasks in defining water bodies is to determine the reference status. The reference state is a state without anthropogenic influence or with insignificant influence. The very good condition of each type of water corresponds to the reference condition. Also, for a certain type of watercourse, community reference agents for phytobenthos, macrophytes, and benthic macroinvertebrates are determined.

In addition to the large number of streams of great importance in the study area are lakes that are, among other things, important for fish fauna, and reservoirs Rama, Jablanica, Grabo-

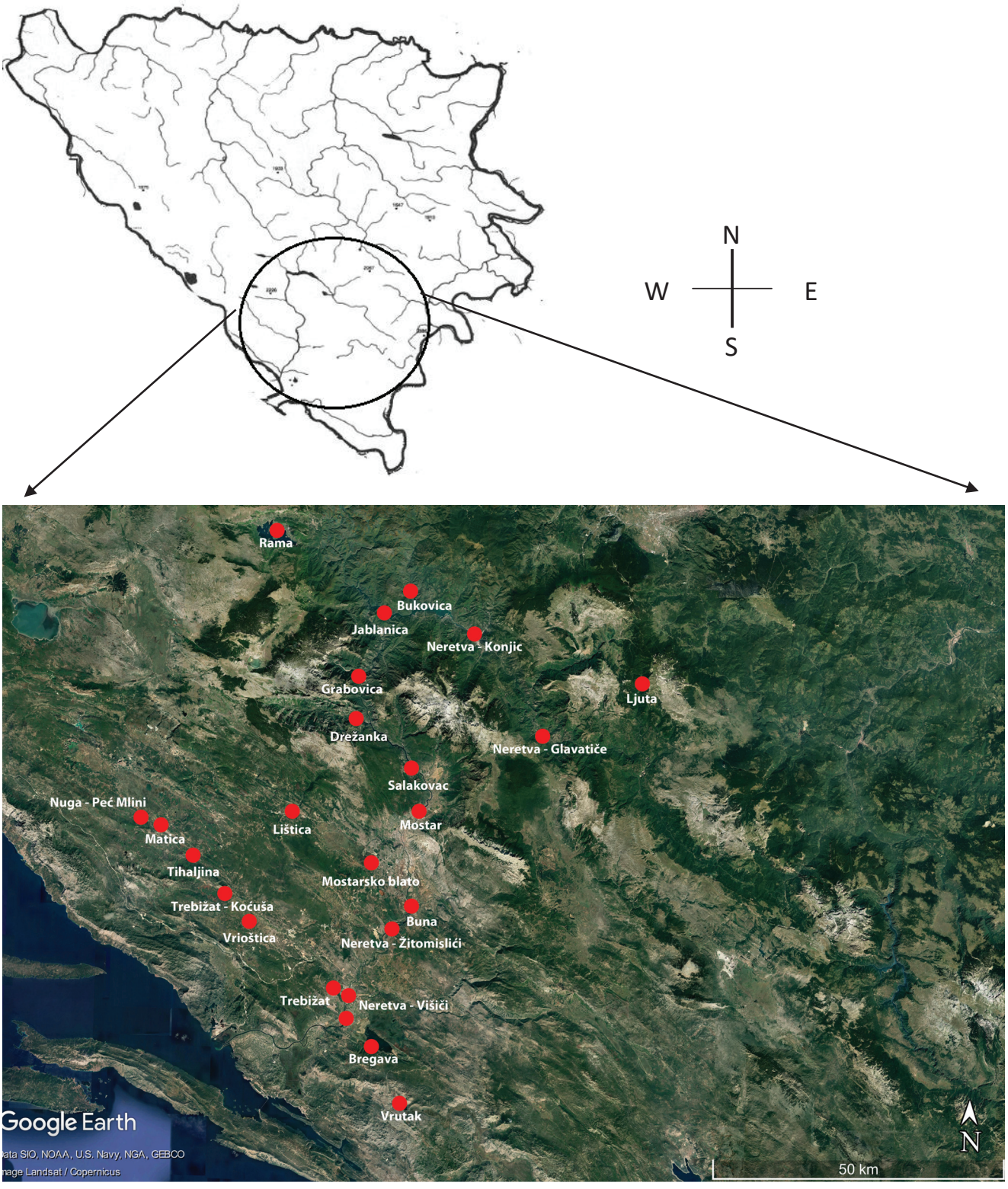


Fig. 1. Research locations on the map of B&H.

vica, Salakovac, Mostar, Svitava, compensation basin Vrutak, and waters of Trebisnjica and Mostar mud, as well as HPP Peć Mlini were built. At maximum waters, the total water surface they have is about 5,500 ha. Each water surface in the investigated area is significant in terms of its characteristics that define representation of aquatic flora and fauna.

Material and methods

Determination of sampling locations

A research of the physical and chemical parameters of water was conducted during 2017 and 2018 at several locations in the Neretva river basin (reservoirs and streams). The surveys were conducted during winter, spring, summer, and fall.

Sampling was carried out at nine sites in the hydro-accumulations: Rama, Jablanica, Grabovica, Salakovac, Mostar, Mostarsko blato, Svitava, Peć Mlini, and Vrutak. In streams, sampling was carried out at 17 localities on the following rivers: Neretva, Rama, Buna, Lištica, Bregava, Drežanka, Rakitnica, Ljuta, Trebižat, Tihaljina, Vrioštica, and Matica (Fig 1).

Data analysis

All water quality parameters were determined in accordance with the American Public Health Association (APHA) methodology (APHA, 1998). Accuracy of each method is prescribed by the APHA methodology.

Water quality indicators were measured *in situ* and in the laboratory to which they were transported, as prescribed by each method. Water temperature, dissolved oxygen content, oxygen saturation, oxygen pressure, salinity, pH, total dissolved solids (TDS) and electrical conductivity (CND) were determined *in situ.* The values of these parameters were measured in the field with a field combined meter, WTW multi-parameter instrument. The device has three separate electrodes designed to measure these parameters.

The following were determined in the laboratory: NO_2^-, NO_3^-, NH_4^+, total nitrogen (TN), total phosphorus (TP), permanganate index, and according to APHA methodology using UV–VIS spectrophotometer (Shimatzu) and the device for Kjeldahl method (Gerhardt).

Results and discussion

Most physicochemical and chemical indicators for Rama accumulation were within the maximum ecological potential, except for the value of electrical conductivity, which indicates moderate ecological potential, and the value of TN, which indicates good ecological potential. The value of the Trophic state index (TSI) was 40.1, which indicates a mesotrophic state, that is, good ecological potential.

For the Salakovac reservoir, most of the physicochemical and chemical indicators were within the values of the maximum ecological potential. The measured values of electrical conductivity showed deviations and indicate good ecological potential, while the value of TP was within the limits of moderate ecological potential. The average annual amount of TP was within the limits of good ecological potential. The average value of the TSI was 46, which indicates mesotrophy, that is, good ecological potential.

Most of the physicochemical and chemical indicators for the Grabovica reservoir were within the limits of maximum ecological potential. Deviations were found in the values of electrical conductivity (good ecological potential) and the value of chlorophyll α (moderate ecological potential). The average value of the TSI was 36, which indicates mesotrophy, that is, good ecological potential.

For the Mostar reservoir, most physicochemical and chemical indicators showed good ecological potential, which is also the case with the waters of the Svitava reservoir.

Physicochemical parameters measured for GKB Trebišnjica were within the limits of maximum ecological potential, except for the value of BOD_5, which was elevated and within the limits of good ecological potential. A mild eutrophic state based on the parameters was observed in Mostar mud and Nuga-Peć Mlini reservoirs. These reservoirs are emptied very quickly in midspring and during the summer period.

In the areas of Glavatičevo and Bukovica, and also in the lower course at the station Višići, the river Neretva had all the physicochemical indicators of water within the limits of maximum ecological potential.

All physicochemical and chemical indicators of water tested on the river Drežanka (Moščenuša) were within the limits of high ecological status, except for the value of ammonia, which indicates good ecological status, but the average annual quantities were below the limit for high status.

The physicochemical parameters of the Ljuta River water were within the limits of high ecological status for the current sample, but the average annual concentrations were within the limits for good status. When it comes to the waters of the river Dušica, the results showed that the examined physicochemical and chemical parameters were within the limits of high ecological status.

At the Neretva-Žitomislići station, all the measured physicochemical indicators of water were within the limits of maximum ecological potential, and at the Neretva-Višići station, they were within the limits of maximum ecological potential. All physicochemical and chemical indicators of water at the mouth of the river Buna were within the limits of high ecological status.

Physicochemical and chemical indicators of water of the river Lištica were within the limits of maximum ecological potential, as well as in the river Bregava in the its upper part. Most of the physicochemical and chemical indicators of water at the Trebižat station were within the limits of high ecological status, except for electrical conductivity, which indicates a moderate state, and nitrate values, which show a good ecological state. The obtained values of electrical conductivity are not surprising since the investigated station had these values, thanks to its geological substrate (from layers of gypsum and anhydride). The stated data is not relevant for the assessment of the ecological condition. The obtained values of nitrates showed small deviations; but the average annual concentrations were above the limits for high ecological status. The same can be stated for the river Tihaljina.

Physicochemical and chemical indicators of Vrioštica water were within the limits of high ecological status. The exceptions are increased values of electrical conductivity (which is characteristic of this watercourse) and nitrate concentrations (good ecological status). At the Vrioštica station, electrical conductivity should not be taken into account during the assessment, since its high values are determined by the geological base. All physicochemical indicators of water on the Matica River were within the limits of high ecological status.

Indicators of physicochemical parameters of water in reservoirs are shown in Tables 1 and 2.

After the analysis and assessment of ecological status, it can be concluded that in terms of most of the measured parameters, all stations are of high ecological status with slight deviations

Table 1. Results of measured physicochemical parameters (*in situ* analysis).

Location	CND (μS cm^{-1})	TDS (mg L^{-1})	Sal. ‰	ρ (kΩ cm)	pH	Temp. (°C)	Dissolved O_2 (mg L^{-1})	O_2 saturation (%)	Pressure O_2 (mbar)
Accumulations									
Rama	325	308	0,1	2,70	8,56	12,8	10,49	107,0	209
Jablanica	330	332	0,1	3,00	8,64	12,5	10,68	103,3	212
Salakovac	351	351	0,1	2,85	8,25	14,4	9,90	97,3	201
Grabovica	297	297	0,0	3,36	8,21	11,8	8,83	85,5	173,3
Mostar	305	305	0,1	3,27	8,4	10,5	11,65	105,0	215
Svitava	202	202	0,0	4,96	8,17	17,3	8,46	88,3	183,3
GKB (Trebišnjica) - Vrutak	217	215	0,0	4,6	8,5	17,6	10,10	106,5	217
Mostarsko Blato	475	474	0,1	1,10	8,6	14,6	8,56	87,1	176,5
Nuga - **Peć** Mlini	231	231	0,0	4,32	8,38	25,6	14,20	170	356
River Neretva – upper stream									
Neretva - Glavatičevo	322	321	0,1	3,12	8,8	14,2	11,09	112,8	224
Neretva - Bukovica	305	305	0,1	3,28	8,8	13,4	11,78	117,8	236
Tributaries of the upper stream of the river Neretva									
Drežanka	318	319	0,1	3,14	8,49	14,1	10,00	99,5	204
Rama	427	426	0,1	2,34	8,50	8,2	11,75	102,1	210
Ljuta	312	12	0,1	-	8,2	-	12,03	114,4	-
Riiver Neretva - downstream									
Neretva - **Žitomislići**	318	317	0,1	3,14	8,6	11,7	13,25	118	252
Neretva - Višići	430	432	0,1	2,32	8,43	12,3	11,9	111,2	232
Tributaries of the lower Neretva River									
Buna	332	331	0,1	3,01	8,4	11,6	14,39	132,8	275
Bregava	350	350	0,1	8,85	8,35	14,8	10,24	107,5	225
Trebižat	1056	1041	0,5	947	8,10	15,5	10,44	105	216
Trebižat - Koćuša	350	351	0,1	2,85	8,35	14,8	10,24	107,5	225,6
Tihaljina	342	342	0,1	292	8,48	18,5	11,60	125,3	256
Vrioštica	731	731	0,1	-	7,6	11,5	11,45	107,7	-
Matica	388	378	0,1	2,58	8,5	17,2	9,35	99,9	202
Lištica	471	471	0,1	-	7,8	12,2	10,30	114,7	-

from good ecological status, in accordance with the Decision on surface and groundwater characterization, reference conditions and parameters for water status assessment and water monitoring (2013). Monitoring the physicochemical characteristics of surface waters is a significant factor in water quality control and management. Surface water quality is influenced by natural processes (e.g., biogeochemical cycles), industrial and municipal wastewater discharges and stormwater runoff from the surrounding catchment area, watercourse redevelopment, and reservoir construction (anthropogenic impact). The construction of dams and other water management facilities has a constant impact on the physical parameters of the aquatic environment. Therefore, the overall water quality is very variable over time as it depends on a number of natural factors and human activities.

Water temperature is a very important indicator that in some reservoirs there are significant fluctuations in water temperature values, for example in the Mostar reservoir in April 2018 in the range of 10.5 °C. There are less oscillations during the year. The water temperature rises to 25.6 °C in the Nuga reservoir (HPP Peć-Mlini), which means that the fluctuations are significant. The duration and volume of winter water mixing is influenced by temperature. Water mixing conditions the vertical distribution of nutrients and oxygen that play a crucial role in the development of planktonic organisms (Straile et al., 2003). The depth of the lake is also associated with the occurrence and extent of anoxia (Keller, Conlon, 1994); lake trophy is also affected by temperature and dissolved oxygen (Bhat et al., 2015).

The value of dissolved oxygen ranged from 8.46 mg L^{-1} in Svitava to 10.68 mg L^{-1} in the Jablanica reservoir, while in Mostarsko blato and the Nuga reservoir, these values were higher. However, in these two reservoirs, the values are quite variable due to frequent changes in the water level. Oxygen saturation ranged from 85.50% in Grabovica to 107% in the Rama reservoir. A higher value was recorded in Mostarski blato and the Nuga reservoir, but these values are variable and are caused by changes in water levels. Artificial reservoirs created for the needs of hydropower plants are systems with a high degree of instability and a pronounced anthropogenic impact (Geraldes, Boavida, 2006). The measured oxygen pressure ranged from 173.30 mbar in Grabovica to 212 mbar in Jablanica, and higher values were measured in the Vrutak and Peć-Mlini reservoirs.

Table 2. Results of measured physicochemical parameters (laboratory analysis).

Location	NH_{4-} N (mg L^{-1})	NO_{3-} N (mg L^{-1})	NO_{2-} N (mg L^{-1})	Total N (mg L^{-1})	Permanganate index (mgO_2 L^{-1})	Total P (mgP L^{-1})
Accumulations						
Rama	0,046	0,17	0,003	1,07	2,18	0,029
Jablanica	0,045	0,12	0024	1,17	1,13	0,021
Salakovac	0,014	0,17	<0,01	<1,0	1,57	0,011
Grabovica	0,173	0,10	<0,01	1,82	4,36	0,042
Mostar	0,039	0,15	0,003	1,32	3,34	0,024
Svitava	0,026	0,12	0,002	1,21	3,25	0,016
GKB (Trebišnjica) - Vrutak	0,015	0,04	<0,01	<1,0	1,66	0,12
Mostarsko Blato	0,039	0,15	0,003	1,32	3,45	0,021
Nuga - **Peć** Mlini	0,096	0,14	0,002	0,84	2,56	0,027
Tributaries of the upper stream of the river Neretva						
Neretva - Glavatičevo	<0,01	0,49	<0,001	<1,00	2,26	0,028
Neretva - Bukovica	0,01	0,97	0,004	<1,00	1,66	0,005
Drežanka	0,151	0,31	<0,01	1,76	3,72	0,006
Rama	0,051	0,36	0,005	1,59	3,28	0,036
Ljuta	0,096	0,422	-	0,559	1,53	0,021
Riiver Neretva - downstream						
Neretva - **Žitomislići**	0,022	0,47	0,004	0,75	3,70	0,039
Neretva - Višići	0,024	0,37	0,003	1,15	4,39	0,023
Tributaries of the lower Neretva River						
Buna	0,021	0,50	0,002	80,89	3,42	0,012
Bregava	0,049	0,34	0,023	0,76	3,70	0,017
Trebižat	0,262	0,88	0,007	1,81	4,55	0,052
Trebižat - Koćuša	0,037	0,44	0,0027	0,99	3,68	-
Tihaljina	0,151	0,433	0,001	1,230	2,53	0,036
Vrioštica	0,022	0,78	-	-	0,87	0,005
Matica	0,122	0,25	0,0026	0,87	1,92	0,031
Lištica	0,042	0,220	-	-	0,262	0,51

Research on fishing waters was conducted by Popović (2010) and on the biological and ecological characteristics of the reservoirs by Kerovec (2002) in the Republic of Croatia. Dissolved oxygen is one of the most commonly used parameters for assessing the state of aquatic ecosystems, and it also affects the solubility of potentially harmful metals (Chapman, 1996). In this study, the dissolved oxygen concentration was inversely proportional to water temperature, which is consistent with Henry's gas law and confirms the fact that the data obtained are adequate for condition assessment and potential trend analysis. The obtained result is in agreement with the results reported by other authors (Villeneuve et al., 2006; Chapra, 2008; Diamantini et al., 2018).

Values of other physical indicators of water in reservoirs were as follows: CND ranged from 202 μS cm^{-1} in Svitava to 351 μS cm^{-1} in Salakovac reservoir, while the highest value (475 μS cm^{-1}) was recorded in Mostarsko blato; TDS ranged from 202 mg L^{-1} in Svitava to 351 mg L^{-1} in Salakovac.

Electrical resistance (ρ) ranged from 3.36 kΩ cm in the Grabovica reservoir to 4.96 kΩ cm in Svitava. The pH value ranged from 8.17 in Svitava to 8.64 in the Jablanica reservoir. The value of NH_4-N ranged from 0.096 mg L^{-1} in the Nuga reservoir to 0.173 mg L^{-1} in the Grabovica reservoir, while the values of NO_3^- N ranged from 0.10 mg L^{-1} in Grabovica to 0.017 mg L^{-1} in the Rama reservoir. NO_2^- N values ranged from <0.01 mg L–^{1} to 0.024 mg L–^{1} in Jablanica. TN ranged from 0.84 mg L^{-1} in the Nuga reservoir to 1.82 mg L^{-1} in the Grabovica reservoir. Permanganate index ranged from 1.13 mg L^{-1} in the Jablanica reservoir to 4.36 mg L^{-1} in the Gabovica reservoir. The total P ranged from 0.011 mg L^{-1} in Salakovac to 0.042 mg L^{-1} in Grabovica. In the context of the management of artificial reservoirs, natural convection, the flow of water mass resulting from the temperature gradient, is a particularly important physical process that can significantly influence the decision-making process and the reservoir management model.

The springs are unique freshwater ecosystems. They represent a link between underground and aboveground habitats that provide specific ecological conditions due to small daily and seasonal temperature fluctuations, especially those sources that depend on groundwater supplies. Changes in abiotic factors in sources are seasonal and sudden in nature (Smith et al., 2005). The water temperature in the springs usually corresponds to the average annual air temperature of the area (Särkkä et al., 1997).

According to Bonacci (1987), the water temperature in the karst springs of Herzegovina ranges from 11 to 14 °C.

According to the results of the analysis, the values of water temperature in streams ranged from 8.2 °C in Rama during April to 18.5 °C in Tihaljina during July, and at Glavatičevo station, in the upper course of Neretva, the temperature in September 2018 was 14.20 °C. The value of dissolved oxygen ranged from 9.35 mg L^{-1} in Matica to 13.25 mg L^{-1} in Neretva (Žitomislić location). Oxygen saturation ranged from 99.90% in Matica to 132.80% in Buna (estuary). The value of CND ranged from 318 $\mu S\ cm^{-1}$in Dežanka to 430 $\mu S\ cm^{-1}$ in Neretva (Višići). The value of TDS ranged from 318 mg L^{-1} in Neretva (Žitomislić) to 432 mg L^{-1} in Neretva (Višići), and a significantly higher value was recorded in Trebižat. Salinity was up to 0.10‰ at all stations, except Trebižat where a value of 0.5‰ was recorded. The value of ρ ranged from 2.32 kΩ cm in Neretva (Višići) to 9.47 kΩ cm in Trebižat. The pH value ranged from 7.6 in Vrioštica to 8.8 in Neretva (Glavatičevo). As for the pH value of water, it did not vary significantly among stations and only a slight increase was observed, while the levels of specific conductivity and alkalinity of water increased at certain stations. In pure waters, the pH is mainly controlled by the balance between carbon dioxide, carbonate, and bicarbonate ions and other natural compounds such as humic acids (Iticescu et al., 2014). However, pH may also indicate the presence of wastewater, especially if measured in conjunction with specific conductivity. Sources of chloride in surface waters are atmospheric precipitation, wear of sedimentary rocks, sewage and industrial wastewater, and runoff of rainwater from agricultural land and roads during winter (Diamantini et al., 2018). The value of NH_4-N ranged from <0.01 mg L^{-1} in Neretva (Glavatičevo) to 0.262 mg L^{-1} in Trebižat. The values of NO_3-N ranged from 0.25 mg L^{-1} for Matica to 0.97 mg L^{-1} in Neretva (Bukovica), and the highest representation was in Ljuta. NO_2-N ranged from <0.001 mg L^{-1} in Neretva (Glavatičevo) to 0.007 mg L^{-1} in Trebižat. TN measured from <1.00 mg L^{-1} in Neretva (Glavatičevo) to 1.76 mg L^{-1} in Dežanka. The permanganate index ranged from 1.53 mg L^{-1} for the Ljuta River to 4.56 mg L^{-1} for Trebižat. The total P ranged from 0.012 mg L^{-1} in the river Buna to 0.51 mg L^{-1} in Lištica. The Adriatic Sea Basin Agency conducts annual biological monitoring of waters in different seasons of Neretva and Cetina (Mrđen et al., 2018), these studies are in accordance with the monitoring results.

The amount of nutrients in watercourses can vary over time and is often under different influences, either of indigenous or non-indigenous origin (Aherne et al., 2006). Namely, in many basins, the main source of nitrogen pollution is leaching from agricultural land, although municipal wastewater can also be a significant source. As far as phosphorus is concerned, the most important sources are industry and households. According to the European Commission's report on the state of the environment, leaching from agricultural land is responsible for 50–70% of nitrogen, phosphorus, and sulfur pollution, which greatly impairs water quality, and urban runoff (municipal wastewater) contributes to 5–15% of total nutrient pollution. The amounts of total as well as organic nitrogen are highest in the warmer period of the year, which confirms the presence of larger amounts of organic matter, primarily of non-native origin, which is subject to decomposition processes (Diamantini et al., 2018). In addition, it suggests a possible contribution of phosphorus in the degradation of water quality through eutrophication followed by a significant reduction in dissolved oxygen concentration. An important indicator of potential production in a lake is the concentration of TP (Jeppesen et al., 1999). The measured nitrate concentrations are above what is considered the background or natural level, that is, they show that the pollution is acceptable.

Thus, depending on the situation (climatic conditions, anthropogenic impact), specific pollutants and metals as pollutants in water can have different effects on aquatic organisms, which can ultimately affect water self-purification processes (Petlušová et al., 2019). The degradation of water quality and aquatic ecosystems, when it occurs, cannot be explained solely on the basis of monitoring of priority pollutants by analytical chemistry methods. Chemical analyses can identify substances and metabolites, but do not provide information on their biological and ecological effects. Although it is always difficult to establish a causal link between the list of pollutants and the biological effects they cause, it is very important to collect such information to better assess the impact of pollution on freshwater ecosystems. The increase in the number of plants and the total fresh mass of plants in the Lemna test are important indicators of the impact of pollution in the environment (Juneau et al., 2003; Radić et al., 2010). Environmental conditions significantly affect the content and composition of photosynthetic pigments in plants (Esteban et al., 2015).

Conclusion

For the life of Neretva-endemic fish, the ecological conditions of the Neretva reservoirs are not similar to the conditions in the natural course of Neretva before the construction of the dam. In the reservoirs, the type of the original habitat of the streams has been completely changed to a new lake type of habitat of unstable ecological conditions. Such conditions are suitable for the invasion of a number of allochthonous introduced fish species.

The construction of hydro-reservoirs completely changed the original ecological characteristics of Neretva in the middle course.

The formation of reservoirs has significantly changed the original ecosystems, making them a biological challenge for the adaptation of indigenous species, and has also created the potential for fisheries development by introducing new, mostly carp fish species.

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