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LONG-TERM TRENDS IN THE STRUCTURE AND DYNAMICS OF THE FISH COMMUNITIES IN BUŠKO BLATO RESERVOIR

Aldijana Mušović[1*], Rifat Škrijelj[1], Mahir Gajević[1], Belma Kalamujić Stroil[2], Adi Vesnić[1], Maja Mitrašinović-Brulić[1], Samir Đug[1]

[1] *Faculty of Science, University of Sarajevo, Zmaja od Bosne 33-35, 71 000 Sarajevo, Bosnia and Herzegovina*
[2] *University of Sarajevo-Institute for Genetic Engineering and Biotechnology, Zmaja od Bosne 8 Kampus, 71000 Sarajevo, Bosnia and Herzegovina*

*Corresponding Author, Email: aldijana_bec@yahoo.de

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ABSTRACT

Buško Blato Reservoir, the third largest hydro accumulation in Europe, is situated in the south-eastern part of the karstic Livanjsko Polje Valley. This aquatic ecosystem is distinguished by a very rich ichthyofauna and the presence of four endemic fish species. Numerous studies focus on ichthyological researches of Buško Blato Reservoir. Its ichthyofauna has been exposed to changes in ecological factors, which in turn reflected on the structure and composition of fish populations. The main objective of this paper was to assess the current state and predict future trends in the ichthyofauna structure and dynamics based on the field data and comprehensive analyses of literature data. The results of the research indicated the presence of 11 fish species from four families, which is the largest number of fish species ever recorded in this ecosystem. *Sander lucioperca*, *Lepomis gibbosus*, *Pseudorasbora parva* and *Tinca tinca* were recorded for the first time in this ecosystem, while some previously recorded species were not found. The results of the analyses clearly indicate the presence of natural interspecific competition and significant level of threats to the endemic fish species caused by human activities.

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INTRODUCTION

Due to its geo-historical position, Bosnia and Herzegovina has diverse wildlife, including ichthyofauna with 118 fish species (Sofradžija, 2009) which inhabit drainages of the Black and Adriatic Sea. More than half of the freshwater fish species from the Adriatic Sea basin live in the river Neretva and its tributaries, with over 30 indigenous species from 22 fish families (Glamuzina et al., 2010). The most abundant is the family Cyprinidae with 20 species, Salmonidae with six species, Gobiidae and Mugilidae with three species respectively, and Petromyzontidae with two species (Mrakovčić et al., 2006; 2007). Recent data on the endemism level regarding fish fauna in Bosnia and Herzegovina report 40 endemic species with a usually very restricted area of distribution (Markotić, 2013). Consequently, many of these species are listed in the IUCN Red List (International Union for the Conservation of Nature and Natural Resources) and the Red List of the fauna of the Federation of Bosnia and Herzegovina (Škrijelj et al., 2014).

Unfortunately, in Bosnia and Herzegovina, as in other parts of the Balkans and Europe, fish communities are endangered due to various human impacts, which often have synergistic effects. The strongest pressure on the fish communities in the waters of the Adriatic Sea basin come from the introduction of allochthonous fish species, pollution from both industrial and agricultural sources, regulation of watercourses and habitat degradation (Mrakovčić et al., 2006; Tutman et al., 2008; Piria et al., 2018). Further disturbance of fish populations is caused by the construction of dams and reservoirs, melioration, as well as over-fishing (Cowx, 2002; Weiss, 2018). Notwithstanding the evidence from the field, no adequate protection measures and programs have been implemented yet.

Buško Blato Reservoir was created in the 1970s to produce electricity in the *Orlovac* hydropower plant and to intensify agricultural production (Žujo, 2004). It is situated in the south-eastern part of the karstic Livanjsko Polje Valley in the Cetina river watershed, belonging to the Adriatic Sea basin (Fig. 1).

Surface inflow by the river Ričina is of the utmost importance for the natural hydrographical regime of Buško Blato Reservoir. The maximal amount of water during the highest peak is over 800 million m^3. Buško Blato Reservoir with an area of 57.7 km^2 is the third largest accumulation lake in Europe (Žujo Zekić, 2009). The water regime of the drainage is to a certain extent regulated through the outflow in the subterranean system located at the southern and south-western parts of the reservoir. The fish fund in the reservoir is often under threat due to sudden fluctuations in the water level, particularly during the summer as a result of water discharge of the hydropower plant.

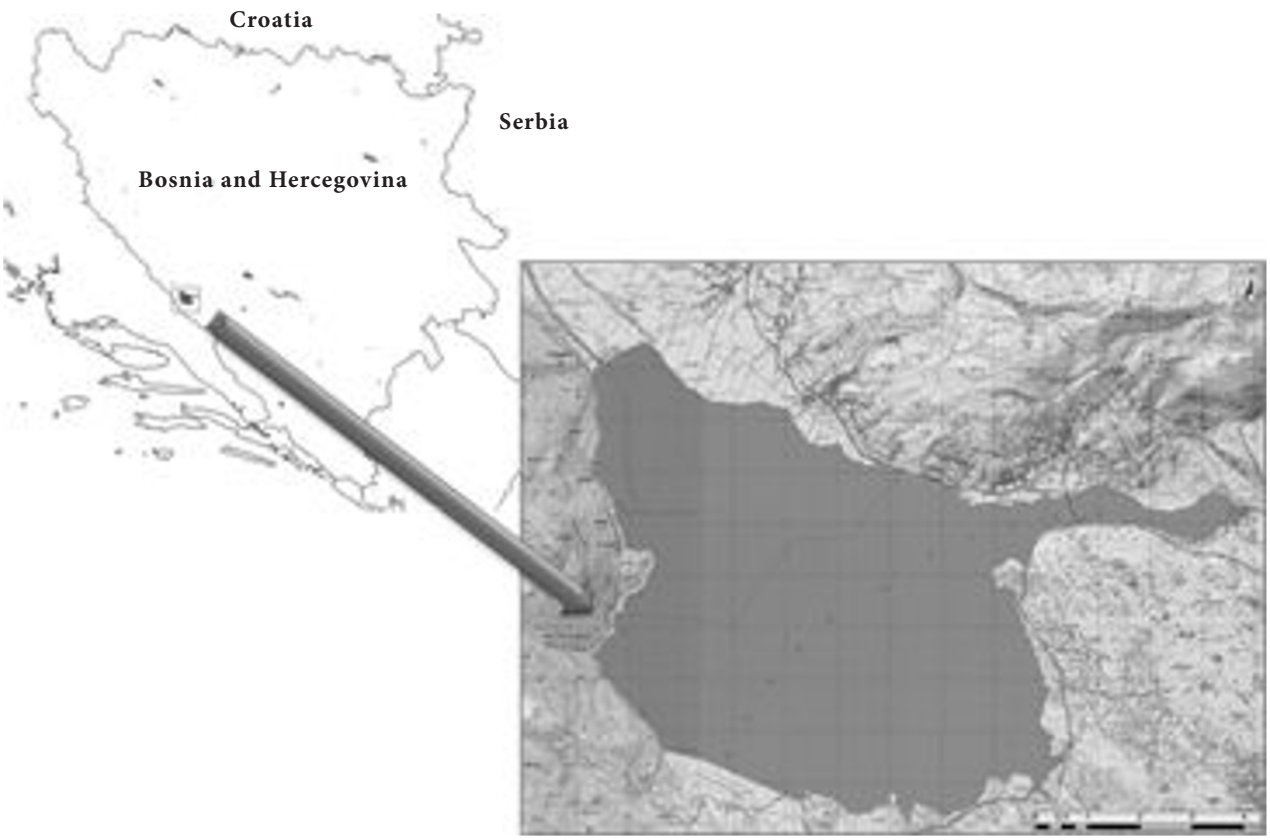

Fig 1. Topographic position of Buško Blato Reservoir

Numerous researchers have focused on ichthyological investigations of Buško Blato, both prior and after the establishment of the reservoir. The earliest surveys date back to the 19th century and the work of Heckel and Kner (1858). The most intensive studies were conducted during the 1960s and 1970s (a detailed overview is given by Žujo Zekić, 2009). According to Aganović et al. (1974), the ichthyofauna of the reservoir consisted of seven fish species from two families: Cyprinidae – *Aulopyge huegelii* (Dalmatian barbelgudgeon), *Chondrostoma phoxinus* (Minnow nase), *Telestes turskyi* (Turskyi dace), *Scardinius dergle* (Bulldog rudd), and Salmonidae – *Salmo trutta lacustris* (Lake trout) and Rainbow trout - *Oncorhynchus mykiss* (Walbaum, 1792). Four species from the family Cyprinidae are stenoendemics (Mučibabić, 1973). Reviewing all possible consequences of establishing the reservoir, Aganović et al. (1974) concluded that it provided suitable living conditions for fishes. However, Škrijelj (2002) argued that ichthyofauna was exposed to changes in the range of ecological factors due to the creation of the reservoirs, which in turn reflected onto the structure and composition of fish communities. Žujo Zekić (2009) stressed that endemic fish populations are endangered due to the interspecific competition with introduced species.

Since biomonitoring programs in Buško Blato Reservoir do not exist, the only reliable data about the structure and dynamics of fish populations come from previous sporadic scientific studies and fisheries management studies. Therefore, the main objective of this paper was to assess the current state and predict future trends in the ichthyofauna structure and dynamics on the basis of the original field data and comprehensive analysis of the data from available literature sources.

MATERIAL AND METHODS

Fish sampling was carried out in Buško Blato Reservoir during September 2015 at seven selected sites (Fig. 2). Electrofishing was carried out at more than 20,000 m^2 of the aquatic surface using electrofishing units Honda EZ 2.200 of 2 kW and ELT 61 II of 2 kW. A standard method for fish sampling in lakes is a multimethod approach which includes the use of gillnets of various mesh size for sampling at different depths. This procedure was carried out in accordance with EN 14757:2005 (CEN, 2005). Garmin GPS was used for recording precise locations of the nets. All gillnets were laid in the afternoon and taken out the next morning in order to include both diurnal and nocturnal fish species.

Morphological identification of specimens was carried out both in the field and in the laboratory at the Ichthyology and Fishing Center at the Faculty of Science, University of Sarajevo, using determination keys (Vuković and Ivanović, 1971; Vuković, 1977; Kottelat and Freyhof, 2007).

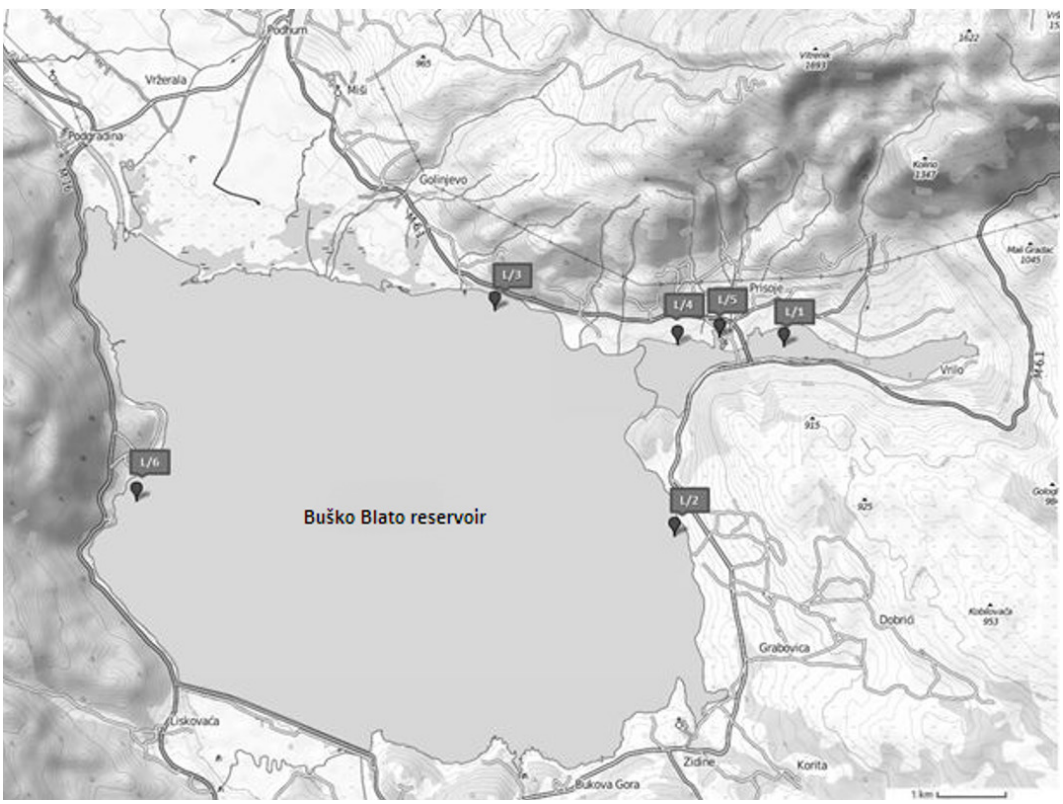

Fig 2. Sampling sites at Buško Blato Reservoir: L1 – Prisoje, L2 - Grabovica, L3 – Golinjevo, L4 – Vrbe, L5 – Bare, L6 – Kamenica

Statistical data analyses

The structure of ichthyopopulations was assessed using Margalef's D index of richness (Margalef, 1968), Shannon diversity index (Shannon and Weaver, 1949) and Simpson's diversity index (Simpson, 1949).

Margalef's index is a diversity index weighted towards species richness. Margalef's Index was calculated following the formula:

$$MD = S-1/LogN,$$

where S = total number of species, N = total density and ni = density of individual species.

Shannon-Weaver index is an information statistic used as a diversity index and is probably the nearest thing to a common standard. It is sample-size dependent and tends to be weighted slightly towards species richness. The Shannon Index was calculated according to:

$$H = -\{ni/ N log10 ni/N\}$$

The species equitability is the ratio of the observed species diversity (H') to the maximum possible for the same number of species in the sample (log S). It is expressed as:

$$J' = H'/log S.$$

If J' = 1, the number of the individual species are evenly distributed among all species in the sample.

Simpson's index gives the probability of any two individuals, drawn at random from an infinite community, belonging to different species. It is an *intrinsic* diversity index weighted towards equitability. Simpson's Index was computed as:

$$D=\sum(ni/N)^2$$

The analyses of differences in diversity among fishes were performed using BioDiversity Professional Programme v.2.0 (McAleece et al., 1997).

Results from this study were compared to data given by Aganović et al., 1974; Kosorić et al., 1984; Bogut et al., 2007 and Žujo Zekić, 2009.

RESULTS AND DISCUSSION

The results of ichthyological research carried out in September 2015 indicated the presence of 11 fish species (298 individuals) from four families (Table 1, Fig. 3). Contrary to the expectations, the most abundant species was Prussian carp with 120 individuals (38.83%). This species is not a component of native fish community of Buško Blato and its catchment, but was introduced into the reservoir after its establishment, along with some other alien species (e.g. carp, European catfish, etc.). The underrepresentation of indigenous fish fauna in our sample is evident and alarming. Out of seven species reported to constitute the fish community of the reservoir in the time of its creation, we found only three (i.e. Dalmatian barbelgudgeon, minnow nase and bulldog rudd). Similar to previous surveys, no specimens of Turskyi dace were found in our study. According to Mihinjač et al. (2014), endemic species *Telestes turskyi* does not live in this reservoir and waterways in the karstic Livanjsko Polje Valley but inhabits only the rivers Krka and Čikola in Croatia. However, the population of *Telestes turskyi* from the Cetina basin was recently recognized as a separated population named *Telestes (Squalius) tenellus* (Mihinjač et al., 2014).

Comparison of the fish community structure in Buško Blato Reservoir based on available previous studies (Aganović et al. 1974; Kosorić et al. 1984; Bogut et al. 2007; Žujo Zekić, 2009) and our investigation is given in Table 2. Although temporal fluctuations in abundances across species are apparent, the general trend is the decline in population size of all native species. Some reports from the field stated that carp, Prussian carp and European catfish were introduced to the reservoir due to their fishing appeal. Such statement was confirmed by fisheries management study conducted by Bogut et al. in 2007. Same species were also found by Žujo Zekić (2009) and in our sample. However, our survey also revealed the presence of pike-perch (*S. lucioperca*), false harlequin (*P. parva*), tench (*T. tinca*) and pumpkinseed (*L. gibbosus*), allochthonous fish species that are recorded for the first time in this ecosystem. No specimens of brown bullhead (*Ameiurus nebulosus*) and silver carp (*Hypophthalmichthys molitrix*), previously recorded by Žujo Zekić (2009), were present in our findings. Although brown trout was recorded in all previous studies, we did not find any specimens at the investigated sites.

The results of the analyses of the diversity indices based on the composition and structure of ichthyofauna data for the period between 1974 and 2015 are presented in Table 3. The results of Margalef's D Index of richness have the highest values for researches carried out in 2015 (5.658), while the lowest value was in 1974 (3.899). The highest value of Simpson's diversity index (D) 0.331, which indicates the lowest diversity, was recorded for 2009, while the lowest value (0.191) (indicating the highest diversity) was recorded for 1984. The highest value of Shannon Index (0.773) was recorded for our research and the lowest value (0.615) was recorded for 2009. The results of analyses of all diversity indices, except Simpson's, clearly indicate the highest diversity values for our study. Simpson's index is heavily weighed toward the most abundant species, as are in all dominance indices. In our study there were several species with small number of individuals and that is the reason why the value of this index is not the highest.

Although human-driven translocations of alien fish species into Buško Blato Reservoir have been going on since its establishment, data show that they never outnumbered the autochthonous species until recently. Only a decade ago, Žujo Zekić (2009) observed the significant dominance of individuals belonging to indigenous fish species (78%). However, our findings indicate changes in the composition and structure of ichthyopopulations in this ecosystem, with allochthonous fish species composing 87% of the total mass in the gathered sample.

Table 1. Qualitative and quantitative structure of fish populations in Buško Blato Reservoir from this study

Family	Fish species	Unit	Sites						No. of individuals	Weight(kg)
			L/1 Prisoje	L/2 Grabovica	L/3 Golinjevo	L/4 Vrbe	L/5 Bare	L/6 Kamenica		
Cyprinidae (Bonaparte, 1840)	*Squalius tenellus* Heckel, 1843	pcs.	1			7	3	4	15	0.80
		gr.	19.0			318.5	153.0	302.0		
	Chondrostoma phoxinus Heckel, 1843	pcs.		3			2		5	0.17
		gr.		100.5			73.0			
	Scardinius dergle Heckel & Kner, 1858	pcs.		7	4		4		15	0.68
		gr.		388.5	76.0		218.0			
	Aulopyge huegelli Heckel, 1843	pcs.	48			1	5		54	0.63
		gr.	537.6			7.0	85.0			
	Cyprinus carpio Linnaeus, 1758	pcs.		1	2	1		2	6	5.94
		gr.		460.0	838.0	2100		2543.0		
	Tinca tinca (Linnaeus, 1758)	pcs.					3		3	0.09
		gr.					85.5			
	Carassius gibelio (Bloch, 1782)	pcs.		17	36	11	37	19	120	44.67
		gr.		8372.5	15300	924.0	13801	6279.5		
	Pseudorasbora parva (Temminck & Schlegel, 1846)	pcs.	53						53	0.20
		gr.	204.0							
Centrarchidae Berg, L.S. 1958	*Lepomis gibbosus* (Linnaeus, 1758)	pcs.	11				7		18	0.12
		gr.	99.0				21.0			
Percidae Cuvier, 1816/7	*Sander lucioperca* (Linnaeus, 1758)	pcs.	1	2			13		16	0.53
		gr.	8.3	138.0			383.5			
Siluridae Cuvier, 1816	*Silurus glanis* Linnaeus, 1758	pcs.	2	1				1	4	5.19
			3450.0	1100.0				635.0		

Table 2. Comparative overview of ichthyologic investigations in Buško Blato Reservoir

Species	1974	1984	2007	2009	2015
Livno masnica – *Squalius tenellus* Heckel, 1843					15
Minnow nase – *Chondrostoma phoxinus* Heckel, 1843	1140	62	206	252	5
Bulldog rudd – *Scardinius dergle* Heckel & Kner, 1858	72	8			15
Dalmatian barbelgudgeon – *Aulopyge huegelli* Heckel, 1843	683	56	237	1422	54
Brown trout – *Salmo trutta* Linnaeus, 1758	14	67	5	21	
Rainbow trout – *Oncorhynchus mykiss* (Walbaum, 1792)	8				
Carp – *Cyprinus carpio* Linnaeus, 1758			29	89	6
Prussian carp – *Carassius gibelio* (Bloch, 1782)			39	406	120
European catfish – *Silurus glanis* Linnaeus, 1758			8	108	4
Pikeperch – *Sander lucioperca* (Linnaeus, 1758)					16
False harlequin – *Pseudorasbora parva* (Temminck & Schlegel, 1846)					53
Tench – *Tinca tinca* (Linnaeus, 1758)					3
Pumpkinseed – *Lepomis gibbosus* (Linnaeus, 1758)					7
Turskyi dace – *Telestes turskyi* (Heckel, 1843)	989	75	245	412	
Brown bullhead – *Ameiurus nebulosus* Lesueur, 1819				3	
Silver carp – *Hypophthalmichthys molitrix* (Valenciennes, 1844)				1	
Total	**2906**	**268**	**769**	**2714**	**298**

Table 3. Comparative overview of the diversity indices based on the composition and structure of ichthyofauna data for the period between 1974 and 2015

Index	1974	1984	2007	2009	2015
Margalef M Base 10,	3.899	5.522	4.657	4.078	5.658
Simpson's Diversity (D)	0.246	0.191	0.214	0.331	0.234
Shannon H' Log Base 10,	0.637	0.728	0.713	0.615	0.773
Shannon J'	0.754	0.936	0.789	0.681	0.742

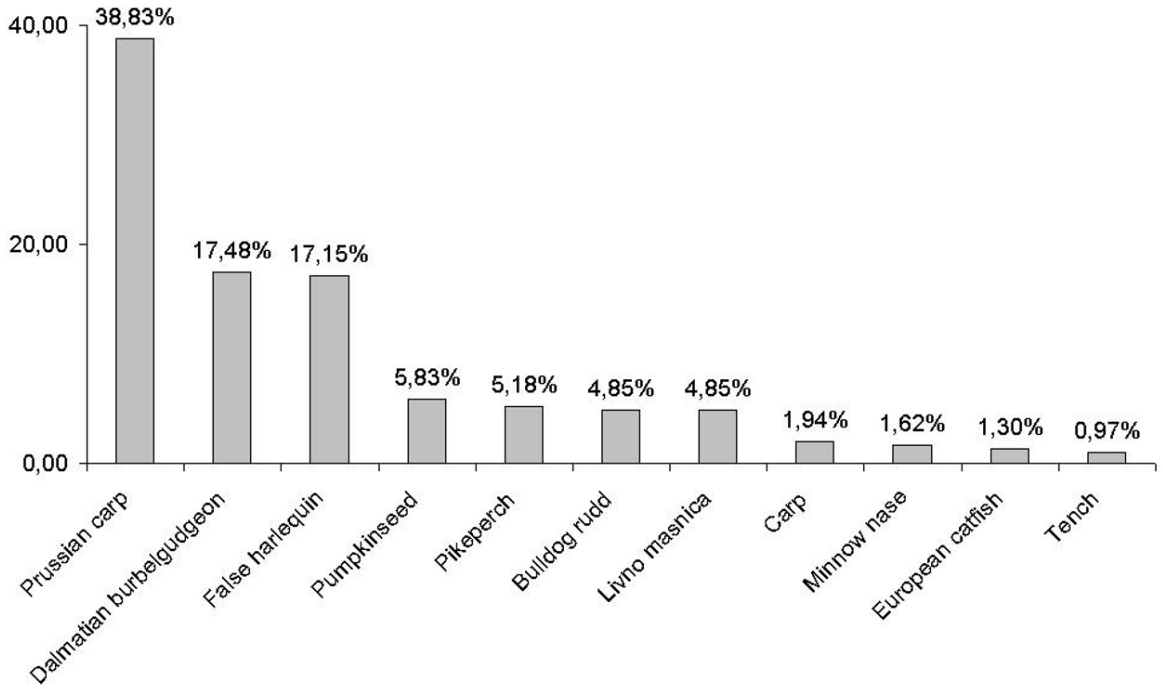

Fig 3. Relative abundance of fish species in Buško Blato Reservoir from this study

Introduced species, which are very often more resistant and more aggressive, could gradually expel native species. Recently, Kalamujić Stroil et al. (2019) reported on population size regression of Dalmatian barbelgudgeon from Buško Blato Reservoir, apparent not only from the reduced abundance but also from somewhat decreased levels of observed genetic diversity. Authors argued that this decline is the consequence of several human-driven stressors acting synergistically, such as competition with invasive species, intensive illegal pouching and susceptibility to occurring pollution caused by the urban run-off and drained agricultural areas surrounding the hydro accumulation.

It has been shown that successful invasive species demonstrate at least one biological feature (e.g. life-history trait or reproductive strategy) which gives them competitive superiority over native species (Olden et al., 2006; MacDougall et al., 2009). Most of the native fish fauna of Buško Blato is represented by species of subterranean waters, therefore exhibiting a rather narrow ecological niche. Conversely, species that have been introduced into Buško Blato Reservoir, such as pumpkinseed, brown bullhead, carp and Prussian carp, particularly, are among the most widely and successfully introduced alien freshwater fish species in Europe (Grabowska and Przybylski, 2015). Rather than genetic variability, the success of invasion is influenced by the plasticity of life-history traits (Valiente et al., 2010). Most of the non-indigenous species of Buško Blato Reservoir are characterized by large body size, tolerance to lower water quality and opportunistic diet regimes. More importantly, these species exhibit diverse reproductive strategies, which is highly valuable when occupying novel ecological niche. Grabowska and Przybylski (2015) examined the reproductive traits of 59 freshwater species invading the waters of Central Europe and categorized them accordingly. Group A, which includes brown bullhead, false harlequin and pumpkinseed, is characterized by early maturation, multiple spawning events, an extended breeding season and parental care. Group C, which comprises catfish and pikeperch, displays different spawning scenarios, usually hide their brood and have large eggs and larvae. Finally, group D, which involves tench, carp and Prussian carp, shows late maturation, high maximum fecundity and is very variable in spawning interval and frequency of spawning events. Whether any of these life-history traits provide a significant advantage to invasive species over the autochthonous ichthyofauna of Buško Blato Reservoir, and if so to which extent, can only be hypothesized as even some basic biological data on these species are scarce or non-existent.

Our study provided an overview of qualitative and quantitative changes in the structure of native fish fauna of Buško Blato Reservoir over the course of time since its establishment. We believe that its decline was driven by a number of human-directed activities which were not accompanied by proper and optimal mitigation and protection measures. This is particularly the case with compensations of losses to local fish communities caused by long-term or accidental mechanical damages in the

riverbeds and the coastal zone, and other registered forms of degradation and destruction of hydro resources. Based on the observed findings, it can be concluded that immediate, proper and systematic measures are needed in order to stop further decline of the indigenous fish community. The urgency for such actions is underlined by the reports from the field that multiple sampling campaigns in Buško Blato Reservoir during 2019 did not retrieve any specimen of endemic species (Spasojević, P., pers. comm.). It is, therefore, proposed that fishing of native fish species should be permanently prohibited as well as stocking with allochthonous fish. Furthermore, watercourse Prisoje around the spring Vrila should be protected as the fish spawning ground. The main reasoning for this is the fact that only in this part of Buško Blato Reservoir the number of mature female individuals of Dalmatian barbell gudgeon, stenoendemic species, at the verge of extinction in this ecosystem, were found (Mušović, 2016; Mušović et al., 2018). Currently, this part of the reservoir is under a significant human impact, mainly due to the pollution from the cattle farm in Tomislavgrad which has no collectors for wastewater treatment. Also, the controlled fish farming of indigenous species should be established. All individuals intended for growth program and stocking must pass a detailed genetic characterization using a set of diagnostic complementary marker systems. These projects should be carried out by multidisciplinary teams, which would involve the knowledge and skills of ecologists, molecular geneticists, morphologists, veterinarians, owners of local fish farms, etc. Finally, to secure the success of such actions, it is of high importance to launch educational programs on endemic and endangered fish species in order to raise awareness in local communities and broader public.

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SAŽETAK

DUGOROČNI TRENDOVI U STRUKTURI I DINAMICI RIBLJIH ZAJEDNICA U HIDROAKUMULACIJI BUŠKO BLATO

Akumulacija Buško Blato, treća najveća hidroakumulacija u Europi, smještena je u jugoistočnom dijelu krškog Livanjskog polja. Ovaj vodeni ekosustav odlikuje se vrlo bogatom ihtiofaunom i prisutnošću četiri endemske vrste riba. Ihtiološka istraživanja navedene akumulacije bila su u fokusu brojnih istraživanja. Ihtiofauna Buškog Blata bila je izložena promjenama različitih ekoloških čimbenika, što se odrazilo na strukturu i sastav ribljih populacija. Glavni cilj ovog rada bio je procijeniti trenutno stanje i predvidjeti buduće trendove u strukturi i dinamici ihtiofaune na temelju prikupljenih terenskih podataka i sveobuhvatnih analiza iz literaturnih podataka. Rezultati istraživanja pokazali su prisutnost 11 vrsta riba iz četiri porodice, što je najveći broj vrsta riba ikada zabilježenih u ovom ekosustavu. S*ander lucioperca, Lepomis gibbosus, Pseudorasbora parva,* i *Tinca tinca* prvi su put zabilježeni u ovom ekosustavu, dok neke prethodno zabilježene vrste nisu pronađene. Rezultati analiza jasno ukazuju na prisutnost prirodne interspecifične konkurencije i značajnu razinu ugroženosti endemskih vrsta riba uzrokovanu ljudskim aktivnostima.

Ključne riječi: endemske vrste, ihtiofauna, međuvrsna konkurencija, invazivne vrste

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