INTRODUCTION OF NEW FISH SPECIES IN BORAČKO LAKE OVER THE LAST 20 YEARS*

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Original scientific paper

Abstract

Boračko Lake is a natural mountain and glacial lake located at the base of the Prenj mountain, at an elevation of 397 meters. From the ichthyological aspect, this lake was originally of a salmonid character, inhabited exclusively by lake trout. However, over the past few decades, the ichthyofauna of this lake has been significantly changed due to the introduction of other fish species. Ichthyological research conducted at Boračko Lake in 2003, 2011 and 2018 revealed the presence of several new fish species, predominantly cyprinids (fish from the order Cypriniformes). Only a small number of individuals of salmonid fish species were registered. Ichthyological research conducted in 2023 confirmed the presence of several new fish species, which were not registered in earlier research. Today, 11 fish species live in Boračko Lake, among which the most numerous are cyprinids (7 species) and they make up 75.3% of the lake's total ichthyopopulation, while salmonids represent two species with a total share of 6.9%. The rest of the ichthyopopulation of this lake is made up of pike-perch with a share of 14.4%, while Neretva spined loach participates with a share of 3.4% of the total ichthyopopulation. In the coming period, a systematic approach is needed to address the issues through selective fishing of non-native (allochthonous) and invasive fish species in order to preserve, protect and restore the populations of indigenous species.

Keywords: *Boračko Lake; salmonids; cyprinids; introduction; research*

INTRODUCTION

The upper course of the Neretva River (geographically defined as the section stretching from its source to the confluence with the Rama River), also known locally as "Upper Neretva," exhibits all the characteristics of a true mountain river, with a gradient of approximately 15‰ (Drešković and Đug, 2010). In the upper Neretva area, a large number of mountain rivers and streams flow into the Neretva River, draining water from the high Bosnian and Herzegovinian mountains: Zelengora, Lebršnik, Živanj, Crvanj, Treskavica, Visočica, Bjelašnica and Prenj (Mihić, 1985; Vegara *et al.,* 2009;

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Muhamedagić, 2014). This area is also characterized by numerous mountain lakes, which are often referred to as "mountain eyes" by locals due to their beauty. Among the largest and most well-known lakes are Kotlaničko, Orlovačko, Jugovo, Crno, Bijelo, Donje bare, Gornje bare, Štirinsko and Kladopoljsko on Zelengora; Veliko, Platno, Crno and Bijelo on Treskavica; Blatačko Lake on Bjelašnica; Uloško Lake on Crvanj and Boračko Lake on Prenj (Sofradžija *et al.,* 2003; Vegara *et al.,* 2009; Drešković and Đug, 2010; Škrijelj *et al.,* 2011; Muhamedagić, 2014). At the foot of the northeastern slopes of mountain Prenj lies Boračko Lake, one of the largest and most famous mountain lakes in Bosnia and Herzegovina (Muhamedagić, 2014). Boračko Lake is oriented northwest-southeast, located on the eastern foothills of Prenj, at an altitude of 397 meters. The basin where the lake formed has a funnel-shaped, amphitheater-like appearance. The lake is surrounded by Crna gora (1,343-1,595 meters) to the southwest, Tranjina (1,055 meters) to the east, Košuta (490 meters) to the southeast, and the steep Krstac (approximately 750-800 meters above sea level) to the north, separating it from the village of Borci (Mihić, 1985; Škrijelj *et al.,* 2011). The surface area of Boračko Lake is 0.241 km², with a maximum depth of 14.0 meters (Drešković and Đug, 2010; Škrijelj *et al.,* 2011).

The rate at which non-native freshwater fishes have been introduced worldwide has doubled in the space of 30 years (Gozlan *et al.,* 2010). Modern ichthyological research started during the same period that Willi Hennig first proposed the approach of phylogenetic systematics for investigating biological questions, following Darwin's concept of natural classification (Chen and Mayden, 2010). The basis of all ichthyological research lies in studying the fish populations in the research area. The primary task of ichthyological research is to identify existing fish populations, ichthyological analyses and obtain relevant data on the presence of specific fish species in the studied locations. The results of ichthyological analyses also provide data on the status of fish populations, their structure and whether the population is in decline, stagnation or growth. Therefore, such research has both fundamental and applied importance for fisheries, as the ultimate aim is to protect the living world of that area, which will certainly be achieved by putting a certain aquatic ecosystem under control and bringing the exploitation of fish populations, i.e. fish stocks, within the limits of reasonable exploitation. The goal of these studies is to assess the structure of fish populations, as well as the distribution of ichthyopopulations in the investigated locations (Hamzić, 2003; Sofradžija *et al.,* 2003; Škrijelj *et al.,* 2011).

In the elaboration of the current state and projections of the protection and improvement of ichthyoresources in the waters of the Konjic municipality, information on the experiences of previous stocking with “indigenous” and non-native species is particularly important, especially when it comes to qualitative and quantitative indicators of these interventions and the origin (regional and population affiliation) of the introduced material. Without a planned and scientifically grounded approach to protecting and harmonizing appropriate food chains in local ecosystems, restrictions on fishing in selected parts of certain watercourses (bans, spawning grounds, etc.) and other complementary measures commonly implemented by sports fishing organizations to

stimulate fish population growth may become self-serving, leading to futile investment of labor and resources. However, we are witnessing frequent unplanned and unprofessional stocking efforts, involving not only new species but also foreign fish species. This method of stocking is particularly vulnerable to indigenous salmonid fish populations, which occupy narrow habitats. Introduced non-native species, which are in many cases more resistant and aggressive, gradually displace indigenous salmonid populations, and in many cases, indigenous populations disappear entirely in such areas (Škrijelj *et al.,* 2011).

MATERIALS AND METHODS

Ichthyological research on the Boračko Lake ecosystem was based on fish samples caught with standard fishing tools, nets and an electrofishing generator. Stationary nets were used with a mesh diameter ranging from 10 to 36 mm. The length of the nets ranged from 25 to 50 m and their height from 1.20 to 6 m. They were tied in sets of 3 to 5 nets in order to cover multiple depth zones across the water flow. The sets of nets were set up in the evening and lifted up in the morning. In addition to the nets, a "Honda" FEG 15.000 (15 kW) electrofishing generator was used in the field. Fishing was conducted at three microlocations in the lake, so different depth zones were covered. The total investigated lake area was 1,500 m². The collected fish samples were processed in the field and returned to their natural habitat, while a smaller number of representative specimens were preserved in 4% formaldehyde and transported to the laboratory of the Center for Aquaculture and Fisheries at the Faculty of Agriculture and Food Sciences in Sarajevo, where they were further processed. During the catch, the fish specimens were properly preserved, labeled, stored at the appropriate temperature and delivered for laboratory analysis. When preparing the samples for laboratory examination, the delivered fish specimens were visually inspected, and after dissection, the internal organs were examined for the presence of appropriate clinical signs of bacterial and parasitic diseases. Systematic fish identification was conducted according to Vuković and Ivanović (1971): Ribe Bosne i Hercegovine; and Kottelat and Freyhof (2007): Handbook of European Freshwater Fishes.

RESULTS AND DISCUSSION

In the ichthyological research of Boračko Lake, which were conducted in 2003 as part of developing the fisheries baseline document (Sofradžija *et al.,* 2003), 7 fish species were registered: lake trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) from the Salmonidae family; and 5 species from the Cyprinidae family (common carp – *Cyprinus carpio*, Prussian carp – *Carassius gibelio*, chub – *Squalius cephalus*, Eurasian minnow – *Phoxinus phoxinus* and schneider – *Alburnoides bipunctatus*). The qualitative and quantitative composition of the ichthyopopulations of Boračko Lake is presented in Table 1.

Table 1. The qualitative and quantitative composition of the fish populations of Boračko Lake in 2003 (Sofradžija *et al.,* 2003)

Order	Family	Species	Abundance	
			Absolute (n)	Relative (%)
Salmoniformes	Salmonidae	Lake trout (*Salmo trutta*)	5	11.40
		Rainbow trout (*Oncorhynchus mykiss*)	3	6.80
Cypriniformes	Cyprinidae	Common carp (*Cyprinus carpio*)	11	25.0
		Prussian carp (*Carassius gibelio*)	5	11.40
		Chub (*Squalius cephalus*)	11	25.0
		Eurasian minnow (*Phoxinus phoxinus*)	1	2.20
		Schneider (*Alburnoides bipunctatus*)	8	18.20
Total		7	44	100.0

Analyzing the data from Table 1 shows a significantly higher abundance of fish belonging to the Cyprinidae family and a notably higher density of their populations. Specifically, common carp and chub make up 50.0% of the total abundance, while schneider, Prussian carp and Eurasian minnow together comprise 31.8%. The remaining 18.2% of the relative abundance consist of salmonid species, with lake trout making up 11.4% and rainbow trout 6.8%. The research has also shown an uneven distribution of certain fish species in different zones of the lake. The qualitative and quantitative structure of the ichthyofauna of Boračko Lake was analyzed on a total sample of 44 individuals (Sofradžija *et al.,* 2003).

According to the literature (Vuković, 1977; Vuković and Ivanović, 1971), Boračko Lake was inhabited exclusively by salmonid fish species, specifically the indigenous lake trout (*Salmo trutta* morpha *lacustris*) and the Ohrid trout (*Salmo letnica*), which was introduced from Ohrid Lake. Therefore, it can be concluded that by the end of the 20th century, at least 6 fish species, mostly cyprinids, had been introduced into Boračko Lake.

Based on the ichthyological research conducted on Boračko Lake in 2011 (Škrijelj *et al.,* 2011), ten fish species from four families of freshwater ichthyofauna (Salmonidae, Cyprinidae, Cobitidae and Percidae) were recorded. Three fish species were registered within the Salmonidae family: lake trout, Ohrid trout and peled (*Coregonus peled*); five species from the Cyprinidae family: common carp, Prussian carp, chub, Eurasian minnow and gudgeon (*Gobio gobio*); and one species each from the Cobitidae family (Neretva spined loach – *Cobitis narentana*) and from the Percidae family (pike-perch – *Sander lucioperca*). The qualitative and quantitative composition of the fish populations of Boračko Lake is shown in Table 2.

Table 2. The qualitative and quantitative composition of the fish populations of Boračko Lake in 2011 (Škrijelj *et al.,* 2011)

Order	Family	Species	Abundance	
			Absolute (n)	Relative (%)
Salmoniformes	Salmonidae	Lake trout (*Salmo trutta*)	9	4.10
		Ohrid trout (*Salmo letnica*)	8	3.70
		Peled (*Coregonus peled*)	1	0.50
Cypriniformes	Cyprinidae	Common carp (*Cyprinus carpio*)	49	22.40
		Prussian carp (*Carassius gibelio*)	36	16.40
		Chub (*Squalius cephalus*)	75	34.20
		Eurasian minnow (*Phoxinus phoxinus*)	22	10.0
		Gudgeon (*Gobio gobio*)	6	2.70
	Cobitidae	Neretva spined loach (*Cobitis narentana*)	12	5.50
Perciformes	Percidae	Pike-perch (*Sander lucioperca*)	1	0.50
Total		10	219	100.0

Based on Table 2, it can be concluded that the majority of the total ichthyopopulation (more than ¾) in Boračko Lake consist of fish from the Cyprinidae family, with a total share of 85.7% – chub is the most represented species with a share of 34.2%, common carp is represented with a share of 22.4%, Prussian carp with 16.4%, Eurasian minnow with 10.0%, while gudgeon is represented with a share of 2.7%. Salmonid fish species make up only 8.3% of the total share – lake trout is represented by 4.1%, Ohrid trout by 3.7%, while peled is represented by a share of 0.5%. The rest of the ichthyopopulation of Boračko Lake includes the Neretva spined loach (a representative of the Cobitidae family) with a total share of 5.5%, and pike-perch (a representative of the Percidae family) with a share of 0.5%. A total of 219 fish specimens were caught using electrofishing generator and nets (Škrijelj *et al.,* 2011).

Compared to the results of ichthyological research from 2003 (Sofradžija *et al.,* 2003), 4 new fish species have been recorded: peled, gudgeon, Neretva spined loach and pike-perch, while rainbow trout and schneider were not registered as they had been in the previous research.

The revision of the fisheries baseline document conducted in 2018 (Poljoprivredno-prehrambeni fakultet Sarajevo, 2018) established 9 fish species from six families of freshwater ichthyofauna (Salmonidae, Cyprinidae, Leuciscidae, Gobionidae, Cobitidae and Percidae). Three species from the Salmonidae family were registered: lake trout, Ohrid trout and peled; two species from the Cyprinidae family (common carp and Prussian carp); chub was registered from the Leuciscidae family; gudgeon was registered from the Gobionidae family; Neretva spined loach was registered from the Cobitidae family; while pike-perch was registered from the Percidae family. The

qualitative and quantitative composition of the fish populations of Boračko Lake is presented in Table 3.

Table 3. The qualitative and quantitative composition of the fish populations of Boračko Lake in 2018 (Poljoprivredno-prehrambeni fakultet Sarajevo, 2018)

Order	Family	Species	Abundance	
			Absolute (n)	Relative (%)
Salmoniformes	Salmonidae	Lake trout (Salmo trutta)	6	6.90
		Ohrid trout (Salmo letnica)	4	4.60
		Peled (Coregonus peled)	1	1.10
Cypriniformes	Cyprinidae	Common carp (Cyprinus carpio)	12	13.80
		Prussian carp (Carassius gibelio)	12	13.80
	Leuciscidae	Chub (Squalius cephalus)	38	43.70
	Gobionidae	Gudgeon (Gobio gobio)	4	4.60
	Cobitidae	Neretva spined loach (Cobitis narentana)	6	6.90
Perciformes	Percidae	Pike-perch (Sander lucioperca)	4	4.60
Total		9	87	100.0

Table 3 show that the largest share of the ichthyopopulation in Boračko Lake consist of chub, the only representative of the Leuciscidae family, with a share of 43.7%. Fish from the Cyprinidae family make up 27.6% of the lake's ichthyopopulation, and representatives of this family (common carp and Prussian carp) are equally represented with 13.8% each. Fish from the Salmonidae family account for 12.6% of the total share – lake trout is represented with 6.9%, Ohrid trout with 4.6%, while peled makes up 1.1% of the total share. Gudgeon is the only representative of the Gobionidae family and its share is 4.6%. The Percidae family is represented by pike-perch, also with 4.6%, while a representative of the Cobitidae family (Neretva spined loach) participates with a share of 6.9% of the total ichthyopopulation of Boračko Lake. A total of 87 fish specimens were caught (Poljoprivredno-prehrambeni fakultet Sarajevo, 2018). When comparing ichthyological research conducted in 2018 with previous studies from 2003 and 2011, it can be concluded that no new fish species have been introduced.

In the latest ichthyological research of Boračko Lake conducted in 2023, a total of 11 fish species were registered: two from the Salmonidae family (lake trout and Ohrid trout); two from the Cyprinidae family (common carp and Prussian carp); three from the Leuciscidae family: chub, Eurasian minnow and bleak (*Alburnus alburnus*); and one species each from the Tincidae family (tench – *Tinca tinca*), from the Gobionidae family (gudgeon), from the Percidae family (pike-perch) and one species from the Cobitidae family (Neretva spined loach). Table 4. shows the qualitative and quantitative composition of the fish populations of Boračko Lake.

Table 4. Qualitative-quantitative composition of fish populations in Boračko L. (2023)

Order	Family	Species	Abundance	
			Absolute (n)	Relative (%)
Salmoniformes	Salmonidae	Lake trout (Salmo trutta)	10	5.70
		Ohrid trout (Salmo letnica)	2	1.20
Cypriniformes	Cyprinidae	Common carp (Cyprinus carpio)	29	16.70
		Prussian carp (Carassius gibelio)	31	17.80
	Leuciscidae	Chub (Squalius cephalus)	35	20.10
		Eurasian minnow (Phoxinus phoxinus)	16	9.20
		Bleak (Alburnus alburnus)	2	1.20
	Tincidae	Tench (Tinca tinca)	14	8.00
	Gobionidae	Gudgeon (Gobio gobio)	4	2.30
	Cobitidae	Neretva spined loach (Cobitis narentana)	6	3.40
Perciformes	Percidae	Pike-perch (Sander lucioperca)	25	14.40
Total		11	174	100.0

The latest ichthyological research conducted in 2023 shows that the largest share of the ichthyopopulation (over 1/3) in Boračko Lake consist of fish from the Cyprinidae family, with a total share of 34.5%. Within this family, Prussian carp is the most represented species (17.8%), followed by common carp with 16.7%. Fish from the Leuciscidae family make up a total of 30.5% of the ichthyopopulation, with chub being the most abundant species at 20.1%, followed by the Eurasian minnow with 9.2%, while bleak makes up a 1.2% share. Based on the latest research, considering individual fish species, chub is the most abundant species in Boračko Lake. Salmonid fish species are represented with a total share of only 6.9% – lake trout makes up 5.7%, while Ohrid trout makes up 1.2% of the share. Pike-perch, as the only representative of the Percidae family, participates with a share of 14.4%. The Tincidae family is represented by tench with 8%, the Gobionidae family is represented by gudgeon with a share of 2.3%, while the Cobitidae family is represented by Neretva spined loach and this species participates with a share of 3.4% of the total fish population in Boračko Lake. A total of 174 fish specimens were caught.

Compared to the results of previous studies conducted in 2003, 2011 and 2018 (Sofradžija *et al.,* 2003; Škrijelj *et al.,* 2011; Poljoprivredno-prehrambeni fakultet Sarajevo, 2018), 2 new fish species have been introduced into Boračko Lake (tench and bleak). It can also be concluded from recent research that there has been a significant increase in the population of the invasive and highly aggressive pike-perch, which, like

all other introduced fish species, is greatly affecting the constant decline of salmonid fish populations in Boračko Lake.

CONCLUSIONS

According to previous literary references (Mihić, 1985; Vuković, 1977; Vuković and Ivanović, 1971), Boračko Lake was inhabited exclusively by indigenous lake trout and the introduced Ohrid trout, which successfully adapted to the living conditions in the lake and even spawned there. However, at the end of the 20th and beginning of the 21st century, there was a massive, unprofessional and unplanned introduction of foreign fish species into Boračko Lake. Non-native species, in larger or smaller quantities, were introduced by irresponsible fishermen, with the aim of "improving" the lake's ichthyofauna. According to available relevant studies conducted in 2003, 2011, 2018 and 2023, at least 12 fish species have been introduced into Boračko Lake in the last 20 years, most of which are not naturally distributed in the Neretva River basin, i.e. the Adriatic Sea basin (except for the Eurasian minnow and Neretva spined loach). As highly adaptable fish species, and often also large predators such as pike-perch and chub, individuals of these species have become a significant danger for the survival of the native salmonid fish species in Boračko Lake. In addition, some cyprinid fish species, such as common carp and prussian carp, are hosts of numerous parasites and carriers of various diseases, meaning that there is a high possibility of mass illness and death of fish, especially indigenous species. Foreign species have been introduced into Boračko Lake that, due to their eco-biological and other characteristics, represent competitors and predators to indigenous fish, directly competing for the same living conditions, and have significantly disrupted the natural food chains and biological productivity pyramid of the lake. Therefore, it is necessary to implement planned remedial fishing (which is enabled by the Law on Freshwater Fisheries of the Federation of Bosnia and Herzegovina, Article 30.) and permanently remove the entire non-native population from Boračko Lake, creating conditions for the rehabilitation of the indigenous lake trout population.

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INTRODUKCIJA NOVIH VRSTA RIBA U BORAČKOM JEZERU U POSLJEDNJIH 20 GODINA

Sažetak

Boračko jezero je prirodno planinsko i ledničko jezero smješteno u podnožju planine Prenj na nadmorskoj visini od 397 m. Sa ihtiološkog aspekta, ovo je jezero izvorno bilo salmonidnog karaktera, naseljeno isključivo jezerskom pastrmkom. Međutim, u posljednjih nekoliko decenija ihtiofauna ovog jezera je značajno izmijenjena zbog introdukcije, odnosno uvođenja drugih vrsta riba. Ihtiološka istraživanja na Boračkom jezeru koja su obavljena 2003., 2011. i 2018. godine pokazala su na prisustvo nekoliko

novih vrsta riba, među kojima preovladavaju ciprinidne vrste riba (ribe iz reda Cypriniformes). Registrovan je samo mali broj jedinki salmonidnih vrsta riba. Ihtiološkim istraživanjima, provedenim 2023. godine, potvrđeno je prisustvo nekoliko novih vrsta riba, koje nisu bile registrovane u ranijim istraživanjima. Danas u Boračkom jezeru živi 11 vrsta riba, među kojima su najbrojnije ciprinidne (7 vrsta) i one čine 75,3% ukupne ihtiopopulacije jezera, dok salmonide predstavljaju dvije vrste sa ukupnim udjelom od 6,9%. Ostatak ihtiopopulacije ovog jezera čini smuđ sa udjelom od 14,4%, dok neretvanski vijun učestvuje sa udjelom od 3,4% ukupne ihtiopopulacije. U narednom periodu je potrebno uvođenje sistemskog riješavanja problema, kroz selektivni izlov alohtonih i invazivnih vrsta riba kako bi se sačuvale, zaštitile i obnovile populacije autohtonih vrsta.

Ključne riječi: *Boračko jezero; salmonidi; ciprinidi; introdukcija; istraživanje*