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Review of the lampreys (Petromyzontidae) in Bosnia and Herzegovina: a current status and geographic distribution

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Abstract. The general status of lampreys (family Petromyzontidae) in Bosnia and Herzegovina was reviewed to determine the species composition and geographical distribution of this group in the region. This paper reviews the available literature to provide a critical analysis of the current status of lamprey species. According to the available data, their status can be considered as indeterminate, largely due to limited published records. While eight species are recorded as present in the region (*Eudontomyzon danfordi*, *E. mariae*, *E. vladykovi*, *Lampetra fluviatilis*, *L. planeri*, *L. soljani*, *Lethenteron zanandreai*, *Petromyzon marinus*), only three species (*E. vladykovi*, *L. soljani*, *P. marinus*) are confirmed to occur. Their distribution is recorded in waters of both the Danube and the Adriatic Sea catchments. Given the deficiencies in our understanding of the taxonomic status of some populations and knowledge of the geographical distribution of lampreys inhabiting both catchments, research focused on improving understanding of the phylogenetic, morphological and phenotypic traits of lampreys in Bosnia and Herzegovina is warranted to resolve these uncertainties. Problems related to threats and conservation, and future perspectives for protective management strategies are discussed. This paper provides the context for future biodiversity conservation and management with regard to lamprey species in Bosnia and Herzegovina.

Key words: diversity, Sava River catchment, Adriatic Sea catchment, species composition, distribution area

Introduction

The freshwaters of Bosnia and Herzegovina support a fish fauna characterized by high diversity and richness and including many stenoendemic species, with distribution ranges confined to restricted parts of river basins (Crivelli 1996, Kottelat & Freyhof 2007). However, despite this remarkable diversity, the Bosnian and Herzegovinian fish fauna is still poorly known and inadequately described (Tutman

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et al. 2009, 2012, 2013). Zoogeographical analysis of freshwater fishes is incomplete with large areas yet to be comprehensively surveyed, and the distribution ranges for many species are indeterminate (Tutman et al. 2017a). This situation is especially true for the lampreys (family Petromyzontidae), for which species' occurrence, geographical distribution and taxonomy are poorly known. The occurrence of lampreys in the freshwaters of Bosnia and Herzegovina has rarely been recorded and their presence has mostly been noted in taxonomic keys and general reports (Vuković 1963, 1977, Vuković & Ivanović 1971, Sofradžija 2009), without precise indications of sample locations. In addition to the sparse data on their distribution, there is a wider deficiency in information on morphological traits and their biology in general (Tutman et al. 2009). An additional aggravating circumstance is the fact that lamprey taxonomy is complex (Lang et al. 2009). Compared with bony vertebrates, lamprey taxonomy is problematic because they possess a relatively limited number of taxon-specific morphological characters (Docker et al. 1999). Species identification and generic status have been based largely on adult dentition, as well as differences in body proportions, number of myomeres, number and morphology of velar tentacles, and pigmentation (Hubbs & Potter 1971, Richards et al. 1982, Salewski et al. 1995, Potter & Gill 2003, Potter et al. 2015). However, these traits cannot be used for larval stages, making lamprey identification challenging. Their wide distribution and high phenotypic plasticity, coupled with the divergent opinions of taxonomists as to the delimitation of species has complicated the taxonomy of lampreys (Hanel & Andreska 2016, Levin et al. 2016). However, advances in phylogenetic research based on molecular data offers the opportunity to better assess taxonomic relationships (Tagliavini et al. 1994, Lang et al. 2009)

Despite recent publications on freshwater fishes and lampreys of Bosnia and Herzegovina (Bogut et al. 2006, Sofradžija 2009, Glamuzina et al. 2013), lampreys have received relatively little attention, their status remains largely unknown and a comprehensive list of species occurring in the region is lacking. According to the available literature (Vuković 1963, 1977, Kottelat & Freyhof 2007, Sofradžija 2009, Tutman et al. 2009, 2017b), a total of eight species of lampreys have been reported to inhabit the freshwaters of Bosnia and Herzegovina (Carpathian lamprey *Eudontomyzon danfordi* Regan, 1911, Ukrainian brook lamprey *E. mariae* (Berg, 1931), Danube brook lamprey *E. vladykovi* Oliva & Zanandrea, 1959, European river lamprey *Lampetra fluviatilis* (Linnaeus, 1758), European brook lamprey *L. planeri* (Bloch, 1784), Šoljan's brook lamprey *L. soljani* Tutman, Freyhof, Dulčić, Glamuzina & Geiger, 2017, Adriatic brook lamprey *Lethenteron zanandreai* Vladykov, 1955 and Atlantic sea lamprey *Petromyzon marinus* (Linnaeus, 1758). However, given the difficulty of their identification and the ongoing controversy with regard to their taxonomy and the systematic position of some species in this region (Holčík & Šorić 2004, Hanel & Andreska 2016, Levin et al. 2016), records for the area are questionable. In addition, a lack of adult specimens to clarify the current status of species in the region also remains a problem (Tutman et al. 2009).

The ecological, behavioural and phenotypic variability of lamprey species, as well as their distribution, has profound implications for implementing conservation strategies (Hume 2017). It has become apparent that some lampreys should be considered endangered due to human activities (Renaud 1997, 2011), requiring the implementation of conservation programs. Despite challenges regarding their taxonomic designation (Docker et al. 1999, Lang et al. 2009), the success of conservation management of lamprey populations depends on an understanding of the biological characteristics of each species, including habitat preferences. An improved understanding of lamprey biodiversity in different domains (e.g. phylogenetic, morphological, behavioural and phenotypic), as well as a better appreciation of the geographic extent of each species, will be essential to more effectively implement protection and conservation measures (Hume 2017).

At present, a comprehensive picture of the general status and geographic distribution of lampreys in Bosnia and Herzegovina is lacking. The current study aims to present information on the taxonomic status and geographic distribution of lamprey species using data derived from previously published sources. Considering the current state of ichthyological information in Bosnia and Herzegovina, the purpose is also to critically analyse the distribution of previously reported species along with clarification of their current status. This information will provide a baseline for decision-making with regard to conservation requirements for these species in Bosnia and Herzegovina.

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Material and Methods

Bosnia and Herzegovina is a relatively small country, encompassing an area of approximately 50,000 km^2. However, it is traversed by rivers comprising two large European catchments, the larger Danube catchment (sometimes referred to as the Black Sea basin) and the smaller Adriatic Sea basin (Fig. 1). The main part of the Danube catchment is drained by the River Sava and its major tributaries (Rivers Una, Sana, Vrbas, Ukrina, Bosna, Drina), which run towards the northern border of Bosnia and Herzegovina and Croatia, while the Adriatic Sea basin is mostly drained by the River Neretva and its tributaries which empty into the Adriatic Sea in Croatia. The freshwater faunas of the Adriatic Sea basin in Bosnia and Herzegovina are isolated from the Danube catchment by the geographic barrier of the Dinaric mountains, with each region supporting endemic forms, together with some non-endemic species (Vuković 1977, Kottelat & Freyhof 2007, Sofradžija 2009).

This review comprises a list of lamprey species from Bosnia and Herzegovina obtained by collating all available information, including peer-reviewed research articles, conference articles, monographs, books, grey literature, and technical reports. Where available, data from museum collections were also included. Unpublished survey data from field surveys were utilised in cases when the material was collected by the authors personally during field sampling. Additional information on the main threats to lampreys were derived from monitoring surveys carried out over the past twenty years

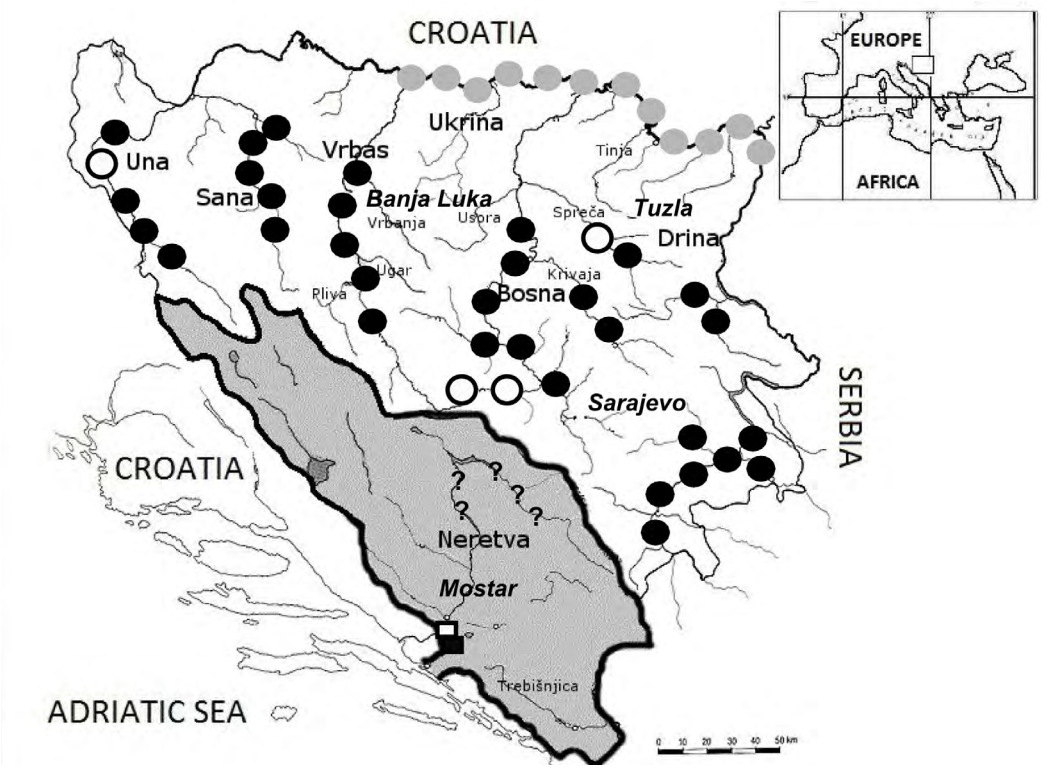

Fig. 1. Geographic distribution of lampreys in Bosnia and Herzegovina based on literature data; grey circles – *Eudontomyzon danfordi* and *E. mariae*, black circles – *Lampetra planeri*, white circles – *Eudontomyzon vladykovi*. White rectangle – *Petromyzon marinus*, black rectangle – *Lampetra soljani*. A question mark indicates locations where lampreys designated as *Lampetra planeri* was recorded in the River Neretva basin (Sofradžija 2009). Danube (or Black Sea) catchment (unshaded), Adriatic Sea catchment (shaded).

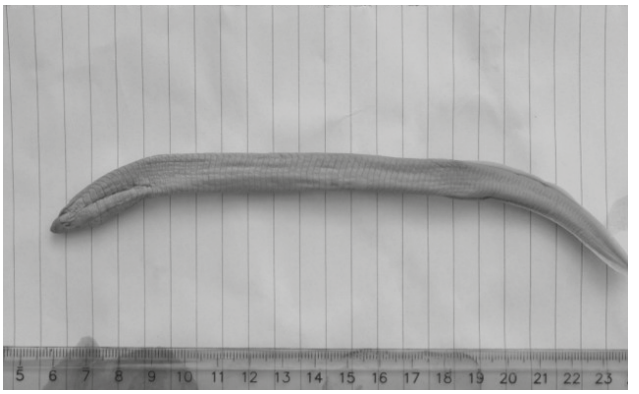

Fig. 2. A specimen from the River Gostelja, an upper tributary of the River Bosna, first mentioned as *Lampetra planeri* (Adrović et al., 2012), but more probably *Eudontomyzon vladykovi* (photo by Avdul Adrović).

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Fig. 3. Po brook lamprey, *Lethenteron zanandreai* (TL = 127 mm), caught on 14 July 2007 in the Hutovo Blato wetland, Bosnia and Herzegovina (photo by Pero Tutman).

in Bosnia and Herzegovina by the Faculty of Science of the University of Sarajevo. To promote the protection and conservation of lampreys, the present paper aims to provide a comprehensive review of the relevant literature together with more recent data gathered by the authors from 2000 to date. In addition, conservation legislation protecting lamprey species and their current status in Bosnia and Herzegovinian is outlined.

In order to clarify the species composition and present status of lampreys in Bosnia and Herzegovina, lamprey samples from the National Museum of Bosnia and Herzegovina, as well as from museums from neighbouring and historically-linked countries were included. Museum collections that were contacted as part of the study include: National Museum – Sarajevo, Bosnia and Herzegovina (NMBH; institutional code follows Kottelat 1997); Croatian National History Museum – Zagreb (HZM), Croatia; Natural History Museum in Belgrade (NHM-B), Serbia; Natural History Museum of Montenegro (NHM-MN), Montenegro; Slovenian Museum of Natural History (SMNS), Slovenia; Naturhistorisches Museum, Wien (NMW), Austria; Hungarian National Museum, Budapest (MNH), Hungary; National Museum Prague (NMP), Czech Republic.

Results and Discussion

Diversity of lampreys in Bosnia and Herzegovina

Based on the available literature, lampreys represent the least studied and poorly known group of freshwater vertebrates in Bosnia and Herzegovina. Even though the investigation of the freshwater fish fauna of Bosnia and Herzegovina dates back to the middle of the nineteenth century (Heckel & Kner 1858), lampreys have received little attention for many years. The bulk of knowledge concerns their general biology and ecology, is mostly based only on species lists and lacks detailed morphological descriptions of species and localities (Vuković 1963, 1977, Vuković & Ivanović

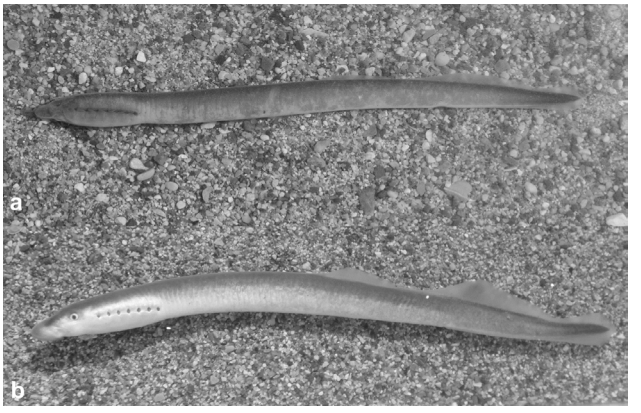

Fig. 4. Šoljan's brook lamprey, *Lampetra soljani*, a) ammocoetes, about 130 mm TL; side-arm of the River Neretva east of Čapljina; 17 Sep. 2014; b) prespawning adult (TL = 127 mm), from lower River Neretva east of Čapljina, Bosnia and Herzegovina 16-17 Jan. 2015 (photo by Pero Tutman).

1971, Sofradžija 2009). Furthermore, species listed in the literature are in obvious conflict with current taxonomy. With the exception of the NMP (Šanda & Vukić 2009), no confirmed lamprey material from Bosnia and Herzegovina is reported to exist in a museum collection. The one exception is a single juvenile of *E. vladykovi* that was collected from the River Una, near Bihać on 26th August 2008; NMP uncatalogued: n = 1J; (leg. Šanda R., Delić A.). Our efforts to locate material from NMBH failed because previously archived samples were lost or destroyed during the war in Bosnia and Herzegovina (1992-1995).

Based on the available data it appears that reports on the presence of some species (*L. fluviatilis*, *L. planeri*) arise from taxonomic errors. It is unlikely that *L. planeri* inhabits Bosnia and Herzegovina because its distribution range is restricted to northern Europe (Kottelat & Freyhof 2007). Records for *L. fluviatilis* are also doubtful. Currently only three species can be confirmed, two from the River Neretva catchment: *P. marinus* (Holčík et al. 2004), and *L. soljani* (Tutman et al. 2017b), and *E. vladykovi* from the River Una in the Danube catchment (Šanda & Vukić 2009).

General overview of the literature

A review of the available literature for the occurrence, composition, taxonomy and geographical distribution of lamprey species in Bosnia and Herzegovina showed data to be scarce with limited reports that have not been expanded upon. The first record belongs to Anonymous (1886), who mentioned the species under the name *Petromyzon fluviatilis* in the River Sava bordering Croatia. Further records were published in the

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Table 1. List of lamprey species and their distribution within the river basins of Bosnia and Herzegovina based on available data.

Species	Rivers-locality	River basin	Catchment	Source
Eudontomyzon danfordi	Sava	Sava	Danube	Vuković (1963, 1977) (as *L. danfordi*), Mrakovčić et al. (2006), Sofradžija (2009)
Eudontomyzon mariae	Dobrinja brook	Bosna	Danube	Zanandrea (1959)
	Drina	Sava		Šorić (1998)
	Sava	Sava		
	Drina	Drina		Sofradžija (2009)
	Bosna	Bosna		
	Vrbas	Vrbas		
Eudontomyzon vladykovi	Una near Bihać	Una	Danube	Šanda & Vukić (2009)
	Lašva	Bosna		Mustafić et al. (2015)
	Spreča, Gostelja			Freyhof J., pers. observ. (2012)
	Fojnica			Freyhof J., pers. observ. (2013)
	Vranica			Golob et al. (2015)
Lampetra fluviatilis	lower River Neretva from Trebižat, Bregava	Neretva	Adriatic	Sofradžija (2009)
Lampetra planeri	rivers and tributaries of Sava basin	Sava	Danube	Vuković (1963)
	rivers of Danube and Adriatic Sea			Vuković (1977)
	Krivaja	Bosna		Kosorić (1981)
	Sava	Sava		Mrakovčić et al. (2006)
	Una	Una		
	Sana	Sana		
	Vrbas	Vrbas		
	Bosna	Bosna		Sofradžija (2009)
	Spreča			
	Drina	Drina		
	upper Neretva	Neretva	Adriatic	
	Spreča	Bosna	Danube	Skenderović et al. (2006), Memić & Adrović (2010)
	Gostelja			Adrović et al. (2012)
Lethenteron zanandreai	Hutovo Blato wetland	Neretva	Adriatic	Tutman et al. (2009, 2012)
Lampetra soljani	lower River Neretva from Buna mouth, Hutovo Blato wetland	Neretva	Adriatic	Tutman et al. (2017a, b)
Petromyzon marinus	lower River Neretva from Buna mouth and their tributaries	Neretva	Adriatic	Vuković (1977), Sofradžija (2009), Holčík et al. (2004), this paper

early 20th century. Zaplata & Taler (1932) were the first to report the presence of lamprey species from Bosnia and Herzegovina. The species, reported as *Petromyzon planeri* (synonym of *L. planeri*), was found in the River Bosna and its tributaries near Sarajevo (the River Bosna flows into the River Sava and forms part of the Danube catchment). Later, Zanandrea (1959) mentioned *E. mariae* from the Dobrinja brook near Sarajevo, which was later questioned by Kux (1969). Valuable faunistic

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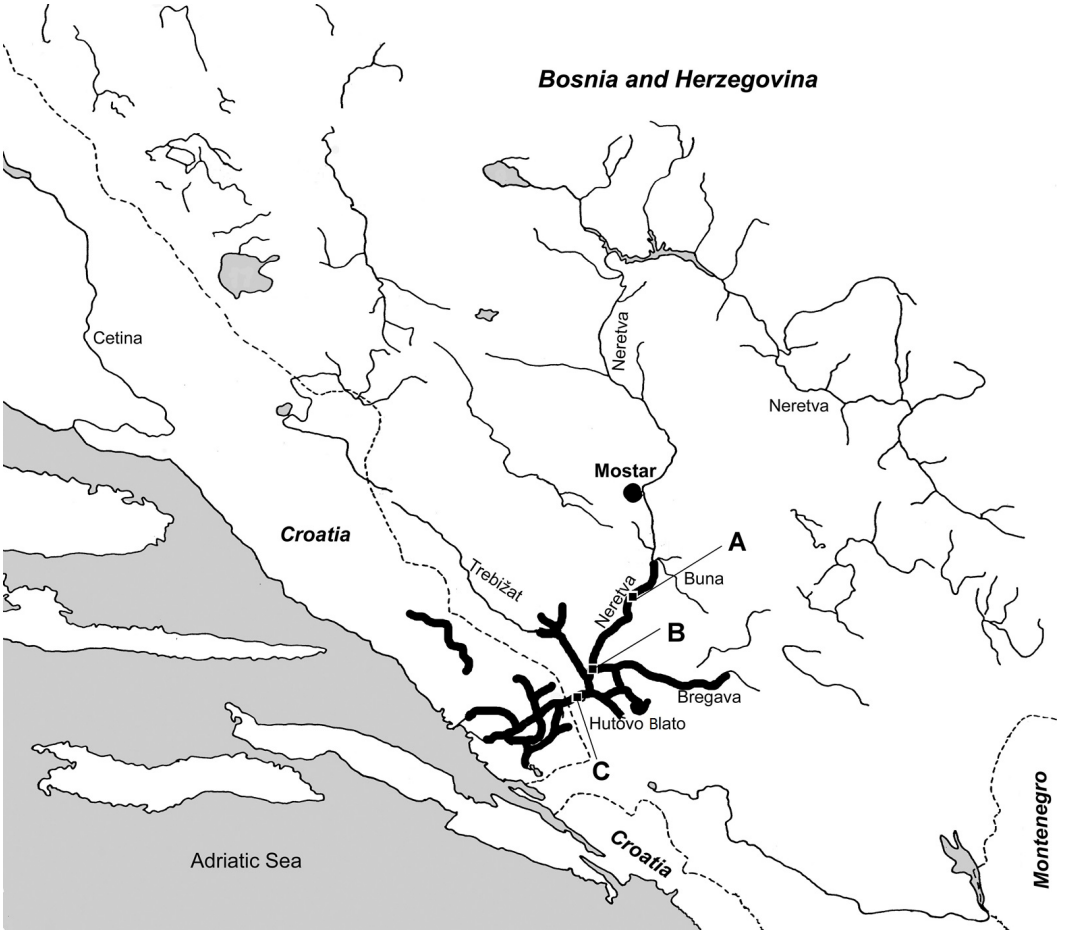

Fig. 5. Records of *Petromyzon marinus* in the River Neretva basin (black squares; A – Žitomislići (Holčík et al. 2004), B – Gabela, C – the River Bregava, a tributary of the Neretva); dark bold line represents geographic distribution of *Lampetra soljani*.

reviews regarding these species were presented by Vuković (1963, 1977). In his book (also a taxonomic key) four lamprey species were listed for Bosnia and Herzegovina along with their distribution; *P. marinus* in the lower River Neretva and its tributaries (Adriatic catchment), *E. danfordi* (as *L. danfordi*) in rivers of the Danube catchment, *L. fluviatilis* in waters of the Adriatic Sea basin and *L. planeri* in both the Danube and Adriatic basin, but with remarks on the uncertain occurrence of *L. fluviatilis*. However, neither examined material and no reference was made to the developmental stages of specimens. Kosorić (1981) reported a lamprey, designated as *L. planeri*, from the River Krivaja (Danube catchment) based on a collected specimen, but without a description. Later, Šorić (1998) studied lampreys from southern Europe (but without including Bosnia and Herzegovina), but listed *E. mariae* in the River Drina, bordering Serbia. Holčík & Delić (2000) in their report of *E. mariae* in Croatia questioned the findings of Zanandrea (1959). The Croatian Red Book of freshwater fish (Mrakovčić et al. 2006) listed three lamprey species, of which *E. danfordi* and *E. mariae* were recorded as historically occurring in the River Sava (bordering Croatia and Bosnia and Herzegovina). Skenderović et al. (2006) mentioned a lamprey species, under the designation *L. planeri*, in the River Spreča (Danube catchment, northern Bosnia and Herzegovina). However, according to Holčík & Delić (2000) *E. mariae* is the only lamprey inhabiting the whole Danube catchment in Bosnia and Herzegovina. In contrast, Kottelat & Freyhof (2007) suggested that *E. vladykovi* is the only lamprey present in this part of Bosnia and Herzegovina. Notably, no taxonomic characteristics of these lampreys have been presented. Bogut et al. (2006) do not include lampreys in their list of Bosnian and Herzegovinian fishes. Although taxonomically lampreys are not fishes, many authors of books and papers formerly included them in lists of fish species.

According to Kottelat & Freyhof (2007) the freshwaters of Bosnia and Herzegovina are inhabited by *P. marinus, L. zanandreai*, but not *L.*

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planeri and *L. fluviatilis*, since these latter species are distributed in western and northern parts of Europe. Following older sources, the list of Bosnia and Herzegovina freshwater fishes by Sofradžija (2009) included five lamprey species: *P. marinus* from waters of the lower River Neretva as far as Žitomislići (about 50 km from the river mouth); *E. danfordi* as a rare species in the lower reaches of the River Sava (Danube catchment), tributaries of the River Drina, as well as the Rivers Bosna and Vrbas; and *E. mariae* from the same area. Sofradžija (2009) additionally mentioned rare occurrences of *L. fluviatilis* in lower parts of the River Neretva and its tributaries the Trebižat and Bregava, whilst *L. planeri* presumably occurs in waters of both the Danube and Adriatic Sea catchments. Šanda & Vukić (2009) collected a juvenile specimen of *E. vladykovi* from the River Una near the town of Bihać. Tutman et al. (2009) presented the first confirmed record of *L. zanandreai* from the Hutovo Blato wetland in the River Neretva basin (Adriatic Sea catchment). This record provided evidence that the original distributional range of this species extended eastward. More recently, Memić & Adrović (2010), as well as Adrović et al. (2012) reported a lamprey under the designation *L. planeri* from the Rivers Spreča and Gostelja (Danube catchment), but without description. Preliminary morphological analysis of these specimens indicated that they were most probably *E. vladykovi* (Freyhof J., pers. comm.).

The reviews of Hamzić & Lelo (2007) and Hamzić (2011) were important in compiling a baseline reference source for the status of lampreys recorded from Bosnia and Herzegovina. In these papers they assumed the incorrect identification of *L. fluviatilis* and *L. planeri* for Bosnia and Herzegovina but supported the presence of *E. vladykovi*. They listed three species of lamprey (*E. danfordi*, *E. mariae*, *E. vladykovi*) for the region, among which *E. vladykovi* was confirmed but with the other two species questionable and needing further work to resolve their status. The publications of Drešković et al. (2011) and Golob et al. (2015) gave support to government institutions in preparation for the Natura 2000 network for Bosnia and Herzegovina. Drešković et al. (2011) listed six lampreys, adding *L. zanandreai* to the previous list, while Golob et al. (2015) mentioned *E. vladykovi* for streams on Mountain Vranica (Danube catchment). A lamprey specimen collected in the River Fojnica (central Bosnia and Herzegovina – Danube catchment) in 2013 was identified as *E. vladykovi* (Freyhof J., pers. comm.). Recently, following the work of previous authors, Milanović et al. (2015) considered the taxonomy of lampreys in Bosnia and Herzegovina, concluding that their taxonomic status has yet to be resolved and their distribution fully characterised. It must be emphasized that not all of these investigations were dedicated exclusively to lampreys and were rarely supported by the examination of collected specimens.

Historical and present distribution

The general and historical local distribution of lamprey species recorded in Bosnia and Herzegovina are listed in Table 1. Based on these records, lampreys were present in the main watercourses of both the Danube (the Rivers Sava, Bosna, Vrbas and Drina) and Adriatic Sea catchment (River Neretva). They were distributed mostly in the upper and middle reaches of large rivers such as the Una, Drina, Bosna and Vrbas, as well in their smaller tributaries (Sava drainage). With the exception of the River Sava, specimens were not recorded in the lower sections of these rivers, or the large karst regions of the Dinaric Alps, such as Duvanjsko, Livanjsko and Grahovsko polje (Adriatic Sea catchment), or smaller and isolated karst regions, such as Mostarsko Blato, Nevesinjsko polje, Dabarsko polje, Fatničko polje (Neretva drainage, Adriatic Sea catchment) (Fig. 1). Hovewer, due to the few precise data for their occurrence and species distributions, it is difficult to pinpoint the exact locations for any taxa since most are mentioned only in incidental reports.

Based on Renaud & Holčík (1986) and Kottelat & Freyhof (2007), *E. danfordi* is generally distributed in the Danube catchment where it is endemic to tributaries of the Tisa and Timis systems of the upper reaches of the Danube in Romania, Slovakia, Ukraine and Hungary. Until the present, data regarding the occurrence and distribution of *E. danfordi* in Bosnia and Herzegovina were scarce and inconsistent. The first record of the species is from Vuković (1963). He mentions the species under the name of *L. danfordi* in the Danube catchment, but without a precise location and voucher specimens. Vuković (1977) repeated the same information. Sofradžija (2009) indicated this species to be rare in the lower reaches of the Rivers Drina, Bosna and Vrbas, and tributaries of the River Sava (Fig. 1).

The distribution of *E. mariae* is reported in catchments of the Baltic Sea (Odra, Vistula, Neman), northern Black Sea (rivers Sava, Drava,

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Danube, except Tisza, Timis, and Cerna, but present in the Prut, Dnieper, Dniester, Don, Kuban, and in rivers in Georgia from the Bzyb' in the south to Chorokhi in the north), Aegean Sea (Vardar), and Caspian Sea (Volga – the River Sura). There is also one record from the upper Morava system (Czech Republic). In the Danube it is restricted to tributaries below the Iron Gates (Kottelat & Freyhof 2007, Freyhof 2011). Data regarding the presence of *E. mariae* are also scarce. The first data for the occurrence of *E. mariae* from Bosnia and Herzegovina pertain to Zanandrea (1959), who mentioned the species from the Dobrinja (tributary of the River Bosna which flows into the River Sava), though this record was questioned by Kux (1969). Later, Šorić (1998) proposed its general distribution in the River Drina. Recent data for the species refer to the lower reaches of the River Sava tributaries (Drina, Bosna and Vrbas) (Sofradžija 2009) (Fig. 1), but without precise location records or voucher specimens.

Eudontomyzon vladykovi is reported from the upper and middle Danube catchment: Sava, Drava systems and west Drava tributaries, and lower Danube catchment. It is locally present in the Timis and Olt systems. It is not recorded from the Tisza and Cerna systems (Kottelat & Freyhof 2007, Freyhof & Kottelat 2008). Until the present, the species was recorded only from four localities in Bosnia and Herzegovina, scattered within the river systems of the Una and Bosna (Šanda & Vukić 2009, Golob et al. 2015) (Fig. 1). Specimens identified as this species were first mentioned in Bosnia and Herzegovina by Šanda & Vukić (2009). The species was discovered in the River Una (Danube catchment) near the town of Bihać. Hamzić (2011) also reported its presence, but with only a general description of its distribution, which overlapped with that of *L. planeri*. Adrović et al. (2012) additionally reported a lamprey under the name *L. planeri* from the River Spreča and Gostelja (Danube catchment), but without description. Preliminary analysis of these specimens (Fig. 2) indicated that they were most probably *E. vladykovi* (Freyhof J., pers. comm.). A lamprey specimen collected in the River Fojnica (central Bosnia and Herzegovina – Danube catchment) in 2013 was identified as *E. vladykovi* (Freyhof J., pers. comm.). Recently, its presence was recorded from streams on Mountain Vranica by Golob et al. (2015) and by Mustafić et al. (2015) in the River Lašva (Fig. 1). Excepting these records, there are no other published data on the distribution of this species.

According to Holčík & Mrakovčić (1997) and Kottelat & Freyhof (2007), *L. zanandreai* was restricted to the upper Adriatic rivers basins, including northern Italy, and the Adriatic Sea catchment of Slovenia and Croatia (the River Neretva and Matica). The occurrence of *L. zanandreai* in Bosnia and Herzegovina was demonstrated by Tutman et al. (2009). Under the designation *Lethenteron zanandreai*, they mentioned the species from the Hutovo Blato wetland in the lower River Neretva. This was the first reliable record (with voucher specimens and a photo) (Fig. 3) of lampreys in Bosnia and Herzegovina. However, according to recent investigations, the freshwater lampreys from the River Neretva catchment belong to a new, independent species *Lampetra soljani* (Tutman et al. 2017b) (Fig. 4). This non-parasitic species is endemic and with a restricted geographical range and narrow habitat requirements. It is distributed in the lower River Neretva catchment in Bosnia and Herzegovina and Croatia, confined to spring-fed streams and canals. It is restricted to the lower section of the River Neretva, from the mouth to about 20 km upstream of the mouth of the River Buna and in the River Neretva tributaries: Tihaljina/Trebižat River system, Krupa, Bregava and Hutovo Blato wetland (Fig. 5). In the past, populations of *Lampetra* from the River Morača (Montenegro) were considered to be *Lampetra planeri* (Šorić, 1998), *Lethenteron zanandreai* (Holčík & Šorić, 2004) and *Eudontomzyon skankokaramani* (Lang et al., 2009). According to the molecular data of Tutman et al. (2017a, b), there are some differences between the populations from the River Neretva and Morača and these may comprise distinct species.

The distribution range of *Petromyzon marinus* covers most of the Atlantic shores of Europe and North America. In northern Europe its occurrence is sporadic and rare, while in Western Europe its largest populations are found in the large rivers that flow into the Atlantic (Kottelat & Freyhof 2007). Less abundant populations are recorded in the Mediterranean, while in the Adriatic Sea it is common along the Italian coast from Bari to the Gulf of Genoa from where it ascends all major rivers (Zanandrea 1957, 1961, 1963). Its occurrence along the eastern Adriatic coast and inflowing rivers has rarely been recorded (Holčík et al. 2004). In Bosnia and Herzegovina Vuković (1963, 1977) and Sofradžija (2009) proposed its occurrence in the lower reaches of the River Neretva (Figs. 1, 5). Only three records of adult *P. marinus* have been

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recorded; one at Žitomislići ca. 50 km upstream (Holčík et al. 2004), one in 2013 near Gabela (city of Čapljina) ca. 25 km upstream, and another in 2014 in the same area (the River Bregava, a tributary of the Neretva) ca. 27 km upstream (Tutman P., pers. observ.). The specimen from Gabela was 55 cm TL, while that from the River Bregava was 82 cm TL.

Threats, legislation and protection

All European lampreys are of conservation concern and some are listed in Annex III of the Bern Convention and in Annex II of the EU Habitats Directive (92/43/EEC). *Petromyzon marinus* is also listed in the OSPAR convention list of threatened and/or declining species. According to the IUCN Red List of Threatened species (IUCN 2016), *E. vladykovi* and *P. marinus* are classified as being of Least Concern (LC), while *L. soljani* was not evaluated. Bosnia and Herzegovina has no list of endangered species, Red Book of Freshwater Fishes and no strategy for implementing conservation or protection measures. There is a Red List of the Fauna of the Federation of Bosnia and Herzegovina (Škrijelj et al. 2013) as one of two entities of Bosnia and Herzegovina. Five lamprey species were included in this list; *P. marinus* as Data Deficient (DD), *E. danfordi* and *E. mariae* as Near Threatened (NT), and *L. fluviatilis* and *L. planeri* as Endangered (EN) species. However, due to the poor understanding of their taxonomic position in Bosnia and Herzegovina, limited knowledge of basic biological features and population viability, there is a pressing need to employ ichthyological surveys for these species as a basis for implementing conservation measures.

To date, no systematic research has been carried out to address the vulnerability of lampreys in Bosnia and Herzegovina and specific threats to lampreys in the region remain largely unknown. Considering the lack of targeted research, the main information on the primary threats to lampreys in Bosnia and Herzegovina can be derived from Škrijelj et al. (2013). Water pollution and habitat loss through modification of river substrates seems to be one of the major threats to lamprey conservation. Lampreys are known to be sensitive to pollution and, although there are no specific data available for Bosnia and Herzegovina, populations from rivers in lowland areas near industrial centres may be susceptible to pollution and at risk. Protracted residence in silt by juvenile lampreys as well as the adults makes them vulnerable to pollution (Maitland 2003). River alterations and engineering works can create impediments to the passage of lampreys during migration to upstream spawning grounds. Lamprey populations from lowland areas are particularly vulnerable to wastewater pollution from urban centres associated with decreased dissolved oxygen concentrations. In some areas, gravel and sand extraction from the riverbed can also constitute a significant habitat impact (Hamzić 2011).

All major rivers identified here as suitable lamprey habitat are under direct threat from hydropower expansion (Hamzić 2011, Škrijelj et al. 2013). While hydropower development is already responsible for considerable loss of river habitats in Bosnia and Herzegovina (e.g. in parts of the River Drina catchment) (Freyhof et al. 2015), much of the historical decline is thought to be a result of pollution (Hamzić 2011, Škrijelj et al. 2013). Pollution is still a major problem in the Bosna and in parts of the River Vrbas (Hamzić A., pers. observ.). In Bosnia and Herzegovina lamprey species have no economic value and are not subjected to economic exploitation. However, in some areas, such as the lower River Neretva catchment, lampreys are sometimes used as live bait for salmonid fishing.

Despite numerous ichthyological surveys conducted in the catchment areas of both the Danube and the Adriatic Sea, there are substantial gaps in our knowledge of the current status and geographical distribution of lampreys in Bosnia and Herzegovina. With the exception of Šanda & Vukić (2009), Tutman et al. (2009, 2017b), Golob et al. (2015) and two unpublished reports on *E. vladykovi*, there is little substantial recent information. Assessing distribution ranges from older reports (Vuković 1963, 1977, Sofradžija, 2009) is problematic, since only general notes are typically given rather than exact locations. However, reliable information on current distributions is necessary for conservation management. While detailed records are currently lacking, it is evident that lampreys are distributed across both catchments in Bosnia and Herzegovina, but more widely in the Danube catchment. Each catchment appears to support different species, with the Danube system inhabited by *E. vladykovi* and showing a wide distributional range. The Adriatic catchment supports *L. soljani* and *P. marinus*, both in the lower River Neretva basin.

For effective species conservation and protection it is imperative to obtain relevant population parameters (Stefanov & Holčík 2007, Hume 2017).

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A critical review of this information will be critical for lamprey biodiversity conservation, especially since lamprey taxonomic validation has undergone substantial changes during the last decade (Blank et al. 2008). To date, attempts to develop an effective population management strategy for lampreys has been obstructed by a deficiency in basic taxonomic (Hamzić & Lelo 2007) and biological information (Hamzić 2011). The most serious difficulties in identification are presented by members of the genus *Eudontomyzon*, which are characterized by the greatest diversity in the region (Holčík & Šorić 2004). It is essential, therefore, to determine species biological, ecological as well as phenotypic traits, which will support more effective protection measures. Population genetic studies have also yet to be conducted for populations in the region. To better conserve lamprey populations, appropriate management policies are needed to target the specific requirements of populations before they reach the status of being threatened or endangered.

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