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Freshwater gobies (Gobiidae) of Bosnia and Herzegovina: a review of the current status and distribution

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Abstract. This review updates the information on the actual status and distribution of freshwater gobies in Bosnia and Herzegovina. The available literature has been critically reviewed to provide more complete and up-to-date information. Consequently four species are proposed for removal from the national checklist, given the lack of any data to support their presence: *Knipowitschia panizzae*, *Pomatoschistus microps*, *Proterorhinus marmoratus* and *Zosterisessor ophiocephalus*. Therefore, the freshwater gobiid fauna is confirmed to include seven species from six genera. The Adriatic Sea basin (Neretva River catchment) is inhabited by three endemic species: *Knipowitschia radovici*, *Orsinogobius croaticus* and *Ninnigobius canestrinii*, while the Black Sea basin (Danube River catchment) is inhabited by the invasive species: *Babka gymnotrachelus*, *Neogobius fluviatilis*, *Neogobius melanostomus* and *Ponticola kessleri*. However, due to the possibility of misidentify the finding of *B. gymnotrachelus* is questionable and needs confirmation. Distribution of both endemic *Knipowitschia* and *Orsinogobius* species is restricted to small areas in the lower Neretva River catchment on both sides of the Croatia-Bosnia and Herzegovina border. The vulnerability of these species is discussed, and the IUCN conservation and units meriting conservation attention were identified. The invasive character of other species is highlighted. This review indicates that the knowledge on the Bosnia-Herzegovinian freshwater gobiid fauna is still far from complete, hence this up-to-date checklist can serve as a basis for further ecological and zoogeographical studies. For better species inventory, finer scale distribution surveys are needed, followed by detailed morphological, molecular phylogenetic and ecological studies.

Key words: review update, species composition, Neretva River basin, Danube River basin

Introduction

The family Gobiidae is the largest teleost family, consisting of more than 2,000 species in more than 200 genera (Fricke et al. 2020). Gobies are small-

sized fishes, rarely more than 110 mm in length. Most species are marine, though there are also many brackish and freshwater representatives. Their distribution includes tropical, subtropical and temperate seas and freshwaters and they are a key

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component of the benthic ichthyofauna (Nelson 2006). The northern and eastern Mediterranean basin, in particular the Balkans and the Black and Caspian Sea basins, host the highest diversity of freshwater gobies in Europe, including many endemic species (Kottelat & Freyhof 2007), dominated by the “sand gobies” (Vanhove et al. 2012). In general, within the Adriatic Sea area, gobies are abundant and widespread, representing one of the most diverse fish families with 52 species presently known (Kottelat & Freyhof 2007, Kovačić & Šanda 2007, Miller & Šanda 2008, Miller 2009, Kovačić et al. 2012, Dulčić & Kovačić 2020). They have adapted to a wide range of habitats, inhabiting mostly marine and brackish waters, while only a few occur exclusively in freshwater (Kottelat & Freyhof 2007, Šanda & Kovačić 2009). On the other hand, recently invasive Ponto-Caspian (P-C) gobies have caused significant changes to the structure of fish assemblage throughout the Black Sea basin. While their presence and geographical distribution in the countries surrounding Bosnia and Herzegovina have been well studied (Zanella 2007, Polačik et al. 2008, Piria et al. 2011a, b, Zanella et al. 2011, 2017, Jakovlić et al. 2015, Horvatić et al. 2016, 2017, Smederevac-Lalić et al. 2019), the situation in Bosnia and Herzegovina is less well characterised (Delić et al. 2014, Nedić et al. 2014, 2018, Čolić et al. 2018).

Despite the remarkable biodiversity of both the Adriatic and Danube basins, the freshwater fish fauna of Bosnia and Herzegovina remains inadequately described (Tutman et al. 2017, 2020). Sound conservation planning depends on a detailed knowledge of biodiversity. However, establishment of conservation priorities is hampered by a poor understanding of taxonomic diversity and geographical distribution (Vanhove et al. 2012, Hume 2017). Current understanding of the diversity and distribution of freshwater gobies in Bosnia and Herzegovina is restricted almost exclusively to general freshwater fish species lists (Vuković 1963, 1977, Bogut et al. 2006, Sofradžija 2009, Glamuzina et al. 2013), without detailed data on their distribution, ecology or biology. Morphometric measurements and meristic characteristics of specimens are rarely matched with exact locations, such as Tutman et al. (2013) for *Ninnigobius canestrinii*. The diversity of freshwater sand gobies in the lower Neretva River is inadequately described, as illustrated by recent descriptions (Kovačić 2005) and new data on geographical distributions (Šanda et al. 2008, Šanda & Kovačić 2009). Recent phylogenetic analyses have provided new insights into the molecular

relationships within sand goby genera, supporting generic changes in *Orsinigobius* and *Ninnigobius* (Geiger et al. 2014, Thacker et al. 2019). There are also preliminary data concerning the ambiguous taxonomy within the genus *Knipowitschia* from the Hutovo Blato wetland in the Neretva River catchment (Glamuzina et al. 2001, 2008, Dulčić et al. 2008, Ahnelt et al. 2009). There is also a growing literature on the occurrence and ongoing spread and proliferation of P-C gobies, which are globally recognized as invasive species (Piria et al. 2011a, b, 2016, Delić et al. 2014, Nedić et al. 2014, 2018, Jakovlić et al. 2015, Horvatić et al. 2016, Čolić et al. 2018), within the Sava catchment (Danube basin), in northern Bosnia and Herzegovina bordering Croatia. It is evident that there is a general lack of data and an urgent need to clarify their status.

Detailed data on the distribution of gobies from countries surrounding Bosnia and Herzegovina have been reported in recent years (Mrakovčić et al. 1994, 1996, Bianco 1995, Marić 1995, Povž 1995, Šanda & Kovačić 2009, Horvatić et al. 2017). However, there is currently no detailed inventory of the status and distribution of freshwater gobies in Bosnia and Herzegovina, with the exception of data presented by Šanda & Kovačić (2009) and Tutman et al. (2013).

The aim of this study is to provide an updated checklist of freshwater gobies that has been compiled from the literature to serve as a baseline for future biogeographical studies and conservation-relevant applications.

Material and Methods

Study area

Rivers in Bosnia and Herzegovina fall within two separate catchment systems, separated by the Dinarides mountain range: Black Sea or Danube (38,719 km² or 75.7% of total country surface area) and the Adriatic Sea (12,410 km² or 24.3%; Fig. 1). Each catchment is characterised by a different ichthyofaunal assemblage: the Black Sea basin is generally inhabited by species widespread in Western, Central and Eastern Europe, while the Adriatic Sea basin is characterized by endemic taxa (Vuković 1977, Kottelat & Freyhof 2007, Sofradžija 2009, Glamuzina et al. 2013). Much of the Black Sea basin is drained by the Sava River and its major tributaries (Una, Sana, Vrbas, Ukrina, Bosna, Brka, Tinja and Drina River). The Sava River is the main waterway basin that forms the border between



Fig. 1. Collection points and geographic distribution of gobies in Bosnia and Herzegovina based on literature data. Black rectangle indicate collection point of *Babka gymnotrachelus*, black circles indicate places where *Neogobius fluviatilis* was recorded, grey circles indicate *Neogobius melanostomus* localities, while white circles show records of *Ponticola kessleri*. Records of gobies in the Neretva River basin – Hutovo Blato wetland (A – *Knipowitschia radovici*, B – *Osinigobius croaticus*, C – *Ninnigobius canestrinii*); thick black lines – distribution area of the *O. croaticus* in the Adriatic Sea watershed. Danube (or Black Sea) catchment (unshaded), Adriatic Sea catchment (shaded).

Croatia, Bosnia and Herzegovina, and Serbia. With its tributaries, it constitutes a major drainage basin of south-east Europe, covering a total area of 97,713.20 km² and it is one of the most significant sub-basins of the Black Sea basin, accounting for 12% of the entire basin (Jukić 2008). The Drina River is the largest and most important of all the Sava tributaries. In contrast, the Adriatic Sea basin of Bosnia and Herzegovina consists of two catchments: the Neretva and Cetina Rivers. The Neretva River catchment, including the Trebišnjica River watershed, covers an area of 10,100 km² or 81.4% of the total Adriatic Sea basin within Bosnia and Herzegovina, while the Cetina River basin covers 2,310 km² (18.6% of the total Adriatic Sea basin within Bosnia and Herzegovina). The Cetina River catchment is represented only by endorheic fields with exclusively subterranean connections. The Herzegovina region is characterised by a massive karst area (more than 4,000 km²) with

numerous isolated, endorheic water bodies occurring as small springs, streams and rivers.

Data collection

This review focuses on the goby species reported from Bosnia and Herzegovina and is based on a compilation of all available information, ranging from peer-reviewed research articles, conference contributions, monographs, grey literature and technical reports. Information on the main threats were derived from monitoring surveys conducted by the Faculty of Science, University of Sarajevo over the past 30 years.

Results and Discussion

Status and geographical distribution of gobies in Bosnia and Herzegovina

The general distribution, historical data and conservation status of each species were evaluated



and listed. Gobies have been recorded only in the north and south of the country, while for large areas there are no data available. Based on these records, gobies in the Danube basin are present mainly in the main watercourse of the Sava River, while there are some data for its tributary, the Una River. There are more data available for the Adriatic Sea basin, where gobies are distributed in the middle and lower courses of small tributaries of the Neretva River, such as Trebižat and Bregava, and in lakes in the Hutovo Blato wetland, but also in the Rastok field, part of the endorheic Matica River catchment (Fig. 1). Gobies have not been recorded in any of the watersheds of the Cetina River basin, which includes several large, karst fields in the Dinarides mountain range (Duvanjsko Polje, Livanjsko Polje, Glamočko Polje and Grahovsko Polje fields), or in most of the karst fields of the Neretva basin (Mostarsko Blato, Nevesinjsko Polje, Dabarsko Polje, Fatničko Polje, Trebišnjica River).

Based on data from the literature, a total of eleven goby species have historically been reported to inhabit the freshwaters of Bosnia and Herzegovina. The status and distribution of all these reported goby species is discussed briefly below.

Genus: *Babka* Iljin, 1927

Babka gymnotrachelus (Kessler, 1857)

Common name: racer goby; local name: glavočić trkač

This P-C goby species is native to coastal areas of the Black Sea basin with fresh and brackish waters of lower salinities (Kottelat & Freyhof 2007). However, it recently expanded outside its native range and is considered invasive and poses a serious ecological threat (Neilson & Stepien 2009a, Piria et al. 2011a, b). It was first reported in Bosnia and Herzegovina in 2017 as *Neogobius gymnotrachelus*, between the cities of Orašje and Tolisa in the middle part of the Sava River (Nedić et al. 2018; Fig. 1). This was the first record of the species for the Sava River and included 21 specimens. The geographically closest record of this species was in 2011, when two specimens were found near the Drava River confluence with the Danube in Croatia, about 60 km as the crow flies (Šanda et al. 2013). This species inhabits sandy or muddy substrates in well vegetated or high-complexity habitats; it is abundant in backwaters and lentic channels (Kottelat & Freyhof 2007, Vassilev et al. 2012). It has been classified as a species of Least Concern (LC) according to the IUCN Red List classification (Freyhof & Kottelat

2008a), though no national assessment has been made (Škrijelj et al. 2013). It should be considered a non-native species. The report in Nedić et al. (2018) needs further scrutiny due to the lack of a report on species determination.

Genus: *Knipowitschia* Iljin, 1927

Knipowitschia panizzae (Verga, 1841)

Common name: Adriatic dwarf goby; local name: glavočić vodenjak

Knipowitschia panizzae is distributed in the northern Adriatic lagoons and estuaries and in eastern Adriatic transitional waters, but also in other areas (Kottelat & Freyhof 2007, Spinelli et al. 2017). It was first recorded by Vuković (1963) as *Gobius panizzae*, but without information on its distribution. Later, Vuković (1977) reported it as *Padogobius panizzai* in the lower Neretva River (Adriatic basin), while Sofradžija (2009) and Drešković et al. (2011) listed it as *K. panizzae* for the same area. However, it was not included by either Bogut et al. (2006) or Glamuzina et al. (2013). It inhabits fresh and brackish waters of streams, lakes, estuaries and lagoons in shallow, well-vegetated habitats (Kottelat & Freyhof 2007). As no major threats are recognised, it has been categorised as a species of Least Concern (LC) on the IUCN Red List (Freyhof 2011a) and the Red List of Fauna of the Federation of Bosnia and Herzegovina (Škrijelj et al. 2013). However, given the peculiarity of the taxonomy of *K. panizzae*, the status of this species should be re-examined considering Kovačić & Pallaoro (2003) and Šanda & Kovačić (2009), and since its status is unclear or it may be absent, it is proposed that this species should be removed from the current list of species present in Bosnia and Herzegovina.

Knipowitschia radovici Kovačić, 2005

Common name: Norin goby; local name: Radovićevo glavočić

This recently described stenoendemic species (Kovačić 2005) inhabits only the lower Neretva River catchment; in Croatia, it also inhabit the tributary Norin River (Kovačić 2005). For Bosnia and Herzegovina, Dulčić et al. (2008) and Glamuzina et al. (2008) reported the presence of a possible new species assigned to the genus *Knipowitschia* in the Hutovo Blato wetland, located some 10 km from the type locality of *K. radovici* (Kovačić 2005). Subsequently, Ahnelt et al. (2009) reported it as an unknown species (Fig. 2), though Šanda & Kovačić (2009) determined the Hutovo Blato specimen as *K. radovici*. Tutman et al. (2013) revealed its wider distribution in the Hutovo Blato wetland (Svitava



Fig. 2. Specimen from Hutovo Blato wetland, lower Neretva River catchment, firstly mentioned as unknown species (Ahnelt et al. 2009), but according to Šanda & Kovačić (2009) most probably *Knipowitschia radovici* (photo Pero Tutman).

Lake; Fig. 1). This species inhabits oligotrophic karst freshwaters in running and stagnant water, preferring silty habitats with sparse gravel and rocks (Šanda & Kovačić 2009, Tutman et al. 2013). It has been categorised as Vulnerable (VU; IUCN 2020), though it has not been assessed at the national level (Škrijelj et al. 2013).

Genus: *Neogobius* Iljin, 1927

Neogobius fluviatilis (Pallas, 1814)

Common name: monkey goby; local name: riječni glavoč

Neogobius fluviatilis has a wide distributional range in brackish and freshwater inshore habitats of lagoons, estuaries and rivers in the Azov and Black Sea basins, though it is invasive in the rivers of eastern and northern Europe where it has colonized numerous freshwater habitats (Kottelat & Freyhof 2007, Neilson & Stepien 2009a). Over the past 20 years, its rapid upstream expansion has been recorded in the Danube and Sava Rivers (Piria et al. 2011a). Vuković (1977) was the first to record the presence of *N. fluviatilis* (as *Gobius fluviatilis*) in the lowlands of the Danube basin in northern Bosnia and Herzegovina, with remarks that this species was rare, but without any precise distribution data; similarly to Bogut et al. (2006) and Sofradžija (2009). Piria et al. (2011a) reported its presence in the Sava River in Croatia near Jasenovac and Gradiška, while Nedić et al. (2014) reported it in the Sava in Bosnia and Herzegovina, collecting 36 specimens on the Bosnian side of the Sava River between Bosanski Šamac and the Brčko District. Delić et al. (2014) reported just two specimens in the Una River at Bosanska Kostajnica, which suggests rapid expansion into this river. Its presence in the Croatian section of the Sava and its tributaries was further reported by Jakovlić et al.

(2015), Horvatić et al. (2016) and Piria et al. (2016; Fig. 1), where it prefers calm and standing waters on open sandy or muddy substrates (Bogut et al. 2006). It is categorised as a species of Least Concern (LC) in both IUCN Red List (Freyhof & Kottelat 2008b) and the national Red List (Federation of Bosnia and Herzegovina; Škrijelj et al. 2013). It should be considered non-native and potentially invasive (Piria et al. 2011a, Delić et al. 2014).

Neogobius melanostomus (Pallas, 1814)

Common name: round goby; local name: glavočić okrugljak

This species is native to the Azov, Black and Caspian Sea basins (Kottelat & Freyhof 2007), though in recent decades it has been rapidly spreading throughout most of Europe (Piria et al. 2011b). It inhabits brackish and freshwater lagoons and lakes, large rivers on sandy and rocky substrates (Kottelat & Freyhof 2007). Despite several reports of its distribution in the Croatian section of the Sava River (Jakovlić et al. 2015, Piria et al. 2016), since the first report in 2011 (Piria et al. 2011b), only one publication is available for Bosnia and Herzegovina (Čolić et al. 2018; Fig. 3), reporting its occurrence at two locations; in the Una River near Kozarska Dubica, and in the Sava River near Gradiška (Fig. 1). The large number of individuals (43) collected in a relatively short time (≈ 1 hour) indicates the presence of a large population in this area. Its conservation status is categorized as Least Concern (LC) in the IUCN Red List (Freyhof 2010), while due to the lack of knowledge of its distributional range, frequency or impact, no national assessment has been made (Škrijelj et al. 2013). However, according to Piria et al. (2011b), it should be considered non-native and potentially invasive.



Fig. 3. Round goby *Neogobius melanostomus* from the Una River in Bosnia and Herzegovina (from Čolić et al. 2018; with the permission of Mr. Goran Šukalo).

Genus: *Orsinigobius* Gandolfi et al., 1986

Orsinigobius croaticus (Mrakovčić et al., 1994)

Common name: Neretva dwarf goby; local name: vrgoračka gobica

This endemic species (Fig. 4) was originally described as the subspecies *Knipowitschia punctatissima croatica* from a restricted area in Croatia (Mrakovčić et al. 1996), which was later considered the valid species: *K. croatica* Mrakovčić et al., 1994 (Kottelat 1997). Following molecular studies by Geiger et al. (2014) and Thacker et al. (2019), it was recently transferred to the genus *Orsinigobius*, as *O. croaticus*. It is distributed only in the karst watercourses of the Adriatic basin in Croatia and Bosnia and Herzegovina. In Croatia, it is found in the Neretva River basin – in the Matica River and springs where it was originally described (Mrakovčić et al. 1996), and in the Jezero and Rastoka fields, Norin River, lower Neretva River, and Modro Oko and Bačina Lakes (Bogut et al. 2006, Mrakovčić et al. 2006, Zanella 2007, Šanda & Kovačić 2009, Čaleta et al. 2015). It was not included for Bosnia and Herzegovina by Sofradžija (2009). Dulčić et al. (2008) suggested its possible presence in the Hutovo Blato wetland, which was later confirmed by Šanda et al. (2008) and Šanda & Kovačić (2009), who extended its distribution to

include several additional localities: in a channel in the Hutovo Blato wetland and the Trebižat River above the Kravica waterfalls. Its current distribution in Bosnia and Herzegovina covers the lower Neretva River up to the town of Čapljina, its tributary Bregava, Trebižat River, and the Hutovo Blato wetland (Šanda & Kovačić 2009, Drešković et al. 2011, Glamuzina et al. 2013, Tutman et al. 2013; Fig. 1). It inhabits oligotrophic, karst, slow-flowing watercourses and lakes with muddy and sandy substrates that are bare or covered with vegetation. It inhabits fresh and slightly brackish waters (0-0.5 PSU), at temperatures up to 24 °C, with stagnant and slowly-moving waters (Šanda & Kovačić 2009). Its reproductive biology and early development were described by Zanella et al. (2011, 2017). According to Mrakovčić et al. (1996), it is assumed to reside underground for part of the year, surfacing in greater numbers at the beginning of the year with corresponding stronger river flow. Based on the available data (IUCN 2020) it is categorized as Vulnerable (VU) at the global level, but as Critically Endangered (CR) at the national level in neighbouring Croatia (Mrakovčić et al. 2006), while a national assessment for Bosnia and Herzegovina has not yet been made (Škrijelj et al. 2013).



Fig. 4. Neretva dwarf goby *Orsinigobius croaticus* (TL = 41.7 mm), lower course of the Neretva River, Bosnia and Herzegovina (photo Davor Zanella).

Genus: *Ninnigobius* Whitley, 1951

Ninnigobius canestrinii (Ninni, 1883)

Common name: Canestrini's goby; local name: glavočić crnotrus

Ninnigobius canestrinii is endemic to the Adriatic Sea basin (Miller 1986). It inhabits brackish and freshwaters, on open sandy or muddy substrates from the Po River Delta (Italy) to the Neretva River in Croatia (Kottelat & Freyhof 2007). It was first reported by Vuković (1963), as *Gobius canestrinii*, but without any distribution data. Later, Vuković (1977), Bogut et al. (2006), Sofradžija (2009) and Drešković et al. (2011) listed it as *Pomatoschistus canestrinii* in the lower Neretva River. Although these authors noted its presence in Bosnia and Herzegovina (lower Neretva River), it has never been officially recorded (Kosorić 1978, Kosorić et al. 1983, Šanda & Kovačić 2009) and exact data on its distribution were only reported in the Croatian part

of the lower Neretva River (Mrakovčić et al. 2006, Šanda & Kovačić 2009), until Tutman et al. (2013) presented the first reliable report of its occurrence in the Hutovo Blato wetland (Bosnia and Herzegovina; Fig. 1), and also provided a photograph (Fig. 5) and morphometric and meristic counts. It is listed as a species of Least Concern (LC) at both the global level and in Bosnia and Herzegovina, given its widespread distribution throughout the Adriatic region (Škrijelj et al. 2013, IUCN 2020). However, in neighbouring Croatia it has been categorised as Endangered (EN; Mrakovčić et al. 2006).

Pomatoschistus microps (Krøyer, 1838)

Common name: common goby; local name: glavočić sićušni

Pomatoschistus microps is a marine and brackish goby with a distribution extending to the eastern Atlantic, from Norway to Morocco, including



Fig. 5. Canestrini's goby *Ninnigobius canestrinii* (TL = 45.2 mm), caught on 25 May 2010 in the Hutovo Blato wetland, Bosnia and Herzegovina (photo Radek Šanda).



the Baltic Sea (Froese & Pauly 2020). In the Mediterranean Sea it is considered rare and its distribution is limited to the north-western part (Patzner 2016). It was firstly reported as *Gobius microps* by Vuković (1963), while Vuković (1977) and Bogut et al. (2006) referred to it as *P. microps* for the lower Neretva River basin. It was not included in Sofradžija (2009). This species is not present in the Adriatic Sea (Dulčić & Kovačić 2020), so all reports from the Neretva River represent misidentification (likely *K. radovici* or *O. croaticus*). Accordingly, it is absent from Bosnia and Herzegovina and should be excluded from the list of fishes.

Genus: *Proterorhinus* Smitt, 1900

Proterorhinus marmoratus (Pallas, 1814)

Common name: tubenose goby; local name: mramorasti glavoč

This species was originally described from rivers draining into the Aegean Sea and the Danube River before being considered synonymous with *Proterorhinus semilunaris* Heckel, 1837; see Manné & Poulet 2008). However, molecular studies of the genus in the Danube basin (Neilson & Stepien 2009a, b) confirmed that *P. marmoratus* is present only in marine and brackish waters at the mouth of Black Sea basin rivers, while inland, freshwater representatives were confirmed as *P. semilunaris*. It was first mentioned in Vuković (1977) as *P. marmoratus* for the lowland waters of the Black Sea basin. Its distribution was not specified, though it was considered rare. This status was later repeated by Bogut et al. (2006), while Sofradžija (2009) listed it for the waters of Sava River. In neighbouring Croatia, *P. semilunaris* is currently recorded only in the Drava River (Čaleta et al. 2019), though there are no reliable data for Bosnia and Herzegovina. Therefore, *P. marmoratus* should be removed from the list, while *P. semilunaris* should not be included in the species list of Bosnia and Herzegovina until its presence can be confirmed.

Genus: *Ponticola* Iljin, 1927

Ponticola kessleri (Günther, 1861)

Common name: bighead goby; local name: bičkaš
Ponticola kessleri is a P-C gobiid that originally inhabited the brackish zone of the northern and western shores of the Black Sea and lower parts of rivers between the Danube and Dnieper (Svetovidov 1964). This highly invasive species was the first P-C gobiid invader of the middle Danube (Brandner 2013) and was previously one of the most abundant and widely distributed invasive gobiids in the upper Danube, starting its range expansion

in the early 1990s (Kováč et al. 2009; reviewed in Roche et al. 2013). For freshwaters of Bosnia and Herzegovina, this species was first mentioned as *Gobius kessleri* by Vuković (1977) in the lowlands of the Black Sea (Danube) basin, without a precise distributional area, and it was considered rare. This status was echoed by Bogut et al. (2006), though as *Neogobius kessleri*, while Sofradžija (2009) listed its distribution for the Sava River and its lower tributaries. Recently, Jakovlić et al. (2015) and Piria et al. (2016) reported its occurrence in the Sava in Croatia (Fig. 1). Although there are currently no reports from the Sava for Bosnia and Herzegovina, this species can be considered present given reports for Croatia; the Sava River forms a border between Croatia and Bosnia and Herzegovina and reports for Croatia are considered to prove its presence in Bosnia and Herzegovina. It inhabits fresh and brackish waters of low salinity (< 2 ppt). It is found in rivers, lakes and lagoons, on rocky or well-vegetated substrates in both lentic and lotic waters (Kottelat & Freyhof 2007). Its conservation status is designated as Least Concern (LC) in the IUCN Red List (Freyhof 2011b) and Data Deficient (DD) in the Red List of Fauna of Federation of Bosnia and Herzegovina (Škrijelj et al. 2013).

Genus: *Zosterisessor* Whitley, 1935

Zosterisessor ophiocephalus (Pallas, 1814)

Common name: grass goby; local name: glavoč travaš
This species inhabits muddy eel-grass meadows in marine and brackish inshore waters of estuaries and lagoons in the Mediterranean, Black Sea, and Azov Seas (Miller 1979). According to Kottelat & Freyhof (2007), *Z. ophiocephalus* has also been recorded as occurring in freshwater, though there is no documented records of its presence. Vuković (1963) first listed this species as *Gobius ophiocephalus*, but without any information on its distribution. Vuković (1977) and Bogut et al. (2006) registered it in the lower Neretva, though it was not included by Sofradžija (2009). It is present in the lowermost sections of the Neretva River in Croatia (brackish and lagoons; Dulčić et al. 2007), but it does not appear to enter Bosnia and Herzegovina. Without clear evidence for its presence, *Z. ophiocephalus* should be removed from the species list of Bosnia and Herzegovina, since there is no information on its occurrence despite its regular incidence in transitional waters.

Overview of the available literature

Though gobies are a large and widespread family that have radiated into marine, brackish and inland



waters of tropical and temperate regions (Nelson 2006, Patzner et al. 2011), most of the documented knowledge of their presence and distribution in Bosnia and Herzegovina consist of recycled comments from general reviews and species lists, without the support of specific evidence of specimens caught (Vuković 1963, 1977, Bogut et al. 2006, Sofradžija 2009, Glamuzina et al. 2013) and typically with little new information (Šanda & Kovačić 2009, Tutman et al. 2013, Deliđ et al. 2014, Nediđ et al. 2014, 2018, Čoliđ et al. 2018). With the exception of Šanda et al. (2008) and Šanda & Kovačić (2009), who were the first to provide a detailed critical review of the occurrence and geographical and ecological distribution of freshwater gobies within the Adriatic Sea catchment, others have avoided critical re-evaluation of the status and presence of gobies, potentially making their reports unreliable. The need for an updated annotated checklist is evident: the previously published list of lampreys and freshwater fish of Bosnia and Herzegovina by Sofradžija (2009) is incomplete, outdated and uses antiquated or erroneous nomenclature. Since then, the current knowledge on the status and distribution of gobies in Bosnia and Herzegovina river basins has been considerably improved. However, the gobies, along with lampreys (Tutman et al. 2020), continue to be the least studied and most poorly known group of fishes in Bosnia and Herzegovina. This situation arises from the lack of targeted research and a detailed revision of reported genera and families. Although considerable challenges remain, by focusing on the resolution of problems in molecular systematics and the identification of threats to endemic species, our hope is to provide the incentive to address these challenges in future research.

Our review of the literature showed that the freshwater gobies of Bosnia and Herzegovina includes six genera with seven species. In contrast with earlier publications (Vuković 1963, 1977, Bogut et al. 2006, Sofradžija 2009), the present study lists four new species (*B. gymnotrachelus*, *K. radovici*, *O. croaticus* and *N. melanostomus*), reflecting developments in ichthyological research, the description of species new to science (Kovačić 2005) and the expansion of invasive species (Deliđ et al. 2014, Nediđ et al. 2014, 2018, Čoliđ et al. 2018). The absence of certain species is also verified, and recent scientific evidence forces us to exclude four species from the current checklist: *K. panizzae*, which is likely a misidentification (for details, see

Kovačić & Pallaoro 2003 and Šanda & Kovačić 2009); *P. microps* considering Kottelat & Freyhof (2007) and Šanda & Kovačić (2009); *P. marmoratus* given the new findings from molecular studies that show it only inhabits marine and brackish water (Stepien & Tumeo 2006, Neilson & Stepien 2009a, b), and *Z. ophiocephalus* for which there was never confirmed evidence of its occurrence.

Generally, in the Black Sea basin, species are widespread in the Ponto-Caspian area, whereas in the Adriatic Sea basin, species are endemic to these waters (Kottelat & Freyhof 2007). Currently, three species of gobies are confirmed from the Neretva River catchment in Bosnia and Herzegovina: *N. canestrinii* (Tutman et al. 2013), *O. croaticus* and *K. radovici* (Šanda & Kovačić 2009, Tutman et al. 2013). Recent studies on the genus *Knipowitschia* in the lower Neretva River catchment (Hutovo Blato wetland) in Bosnia and Herzegovina provided new insights into its taxonomic structure and demonstrated unexpectedly high diversity (Dulčić et al. 2008, Ahnelt et al. 2009). These findings were relevant for zoogeography, taxonomy and conservation issues given the local eco-hydrological conditions, highly restricted distribution and status of the species. However, this finding was later questioned by Šanda & Kovačić (2009), who proved that three goby species (*K. radovici*, *O. croaticus*, *N. canestrinii*) occur in sympatry in the region (Šanda & Kovačić 2009, Tutman et al. 2013). Furthermore, high variability of taxonomically important morphological characters (head canals and squamation) was detected between specimens of *K. radovici*, indicating that this species presents a group of three eco-phenotypes of a nominal taxon (Dulčić et al. 2008, Ahnelt et al. 2009). Such intraspecific variation has already been observed in freshwater goby radiations (Vanhove et al. 2012), suggesting the need for further molecular and morphological work to formally describe the real status of these species. In general, the origin of most freshwater gobies from the Mediterranean and Ponto-Caspian region appears to be the result of the complex hydrological and geological changes over the last 20 million years, leading to faunistic isolation and speciation bursts (Penzo et al. 1998, Huyse et al. 2004, Vanhove et al. 2012, Thacker et al. 2019). The present day goby distribution in these areas is likely to have been influenced by older (Messinian salinity crisis, around 5.96-5.33 Myr; Hsü et al. 1977, Quignard & Tomasini 2000) or more recent events (Pleistocene glaciation cycles; Stefanni & Thorley 2003),



which governed hydrological fluctuations and temperature changes (transition from marine to oligosaline or freshwater conditions; Bianco & Miller 1990, Penzo et al. 1998, Kovačić & Patzner 2011, Vanhove et al. 2012). There are few remaining marine or brackish fishes of pre-Messinian origin in the Mediterranean or Ponto-Caspian areas (Quignard & Tomasini 2000). Therefore, gobies may be a general indicator of paleogeographic and paleohydrographic fluctuations, presenting the promising role of evolutionary significant units (ESUs) for conservation. To preserve these species, detailed morphological, molecular, phylogenetic, behavioural and ecological studies are required.

The report of the presence of *B. gymnotrachelus* (Nedić et al. 2018) in the middle Sava River is informative from a zoogeographical perspective since it indicates the real possibility of successful rapid expansion of this invasive species deep into the river corridor. The last report in the Danube River basin was in the Drava River in Croatia in 2011 (Šanda et al. 2013). Since there have been no reported changes in the *B. gymnotrachelus* population density or range in Croatian inland waters during recent years (Piria et al. 2017), it seems to have spread unnoticed. This finding may indicate that its invasiveness and distribution may be greater than previously assumed (Jakovlić et al. 2015). As the Sava and Una Rivers represents the border between Bosnia and Herzegovina and Croatia, new findings in Croatia could also be considered new information on the species distribution in Bosnia and Herzegovina. These data also suggest the possibility of its further upstream expansion via lowland rivers in Bosnia and Herzegovina. However, in the Nedić et al. (2018), there is no record of how species were identified. Since it is easy to misidentify this species with *N. fluviatilis*, which is abundant in the Sava River, this source is questionable and this finding needs to be confirmed. Non-native fish may have a negative ecological impact on the local environment and given their influence in fish assemblage structure throughout the Sava River catchment (Jakovlić et al. 2015), systemic studies are needed in the near future.

Threats, legislation and protection

Freshwater sand gobies are often presented as a classical example of endemism and of the threatened freshwater fish fauna in the Balkans (Miller 1990, Kottelat & Freyhof 2007, Vanhove et al. 2016). As these species and genera are endemic

to the European fish fauna, they constitute part of the common ichthyological heritage. Their value in this human cultural context may be augmented by their natural role as small predators in freshwater food webs (Miller 1990). Given their presence in unusual habitats, mainly in coastal areas throughout the Balkans, localized distributions in small freshwater ecosystems, and associated high level of endemism, they are considered useful indicators for the conservation of Mediterranean inland aquatic ecosystems (Vanhove et al. 2012). As such, there is a clear need to focus on the isolated and most vulnerable populations, such as those in sensitive habitats at the borders of freshwater and marine ecosystems (Vanhove et al. 2016). However, their conservation status has been neglected for decades, even in well-studied areas.

Only *N. canestrinii* (listed as *P. canestrinii*) and *O. croaticus* (listed as *K. croatica*) are listed in Annex II of the EU Habitats Directive (1992), while according to the IUCN Red List (IUCN 2020), *K. radovici* and *O. croaticus* are classified as Vulnerable (VU), while *N. canestrinii* as Least Concern (LC). Unfortunately, Bosnia and Herzegovina has not compiled a list of endangered species or a Red Book of Freshwater Fishes and no conservation strategies or protection measures have been implemented. There is the Red List of Fauna of the Federation of Bosnia and Herzegovina (Škrijelj et al. 2013) and it lists five gobies species: *P. marmoratus*, *N. canestrinii* (as *P. canestrinii*), *N. fluviatilis* and *K. panizzae* as Least Concern (LC), and *P. kessleri* as Data Deficient (DD). In neighbouring Croatia, the endemics of the Neretva River that are also found in Bosnia and Herzegovina have been categorised at the national level: *O. croaticus* (listed as *K. croatica*) as Critically Endangered (CR), and *N. canestrinii* (as *P. canestrinii*) as Endangered (EN; Mrakovčić et al. 2006). Given the conservation status for these species and the relatively poor understanding of their taxonomic position in Bosnia and Herzegovina, basic biological traits, and habitat ecology, there is an imperative to employ ichthyological surveys as a foundation for future conservation measures.

To date, no systematic research has been carried out to address the vulnerability of endangered endemic gobies species in Bosnia and Herzegovina. The main information on the primary threats to these species comes from Dulčić et al. (2008) for the Hutovo Blato wetland area in the lower Neretva River, though without detailed analysis and impact assessments. Hutovo Blato is a freshwater, inland,



karstic, wetland zone of special protection and a site of community interest, situated about 30 km from the sea. It was declared a nature park in 1995, and a Ramsar Site in 2001. It is connected with the Neretva via the Krupa River from which it receives significant inflows. The Hutovo Blato wetland gobies (like all the other endemic fish species here) are threatened by human-induced long-term trends of environmental degradation, caused by significant hydrological changes. A reduced supply of water from underground sources and from the Neretva has led to a loss of aquatic habitats (Tutman et al. 2019). Another issue is the introduction of alien species, particularly *Lepomis gibbosus* (Glamuzina et al. 2017). Freshwater sand gobies are also under threat from saltwater intrusion (Glamuzina et al. 2019) due to water diversion for hydropower generation in the upper sections of the river. Finally, the potential invasion risks associated with P-C gobies (*B. gymnotrachelus*, *N. fluviatilis*, *N. melanostomus*, *P. kessleri*; Jakovlić et al. 2015), is incompletely understood. Thus, fuller knowledge of all these potential threats is required. In Bosnia and Herzegovina, none of these species have commercial value and are not subjected to economic exploitation. Pollution also remains a major problem in the main Bosnia and Herzegovina rivers (A. Hamzić, pers. observ.).

Because of their narrow habitat range and high level of endemism, especially in the Balkans which is a key centre of endemism and a hotspot of biodiversity (Kryštufek & Reed 2004), the freshwater sand gobies might be considered useful indicators for conservation monitoring of Mediterranean inland aquatic ecosystems (Vanhove et al. 2012). However, there has been no systematic research to address the vulnerability of sand gobies in Bosnia and Herzegovina and specific threats remain unknown, especially in

protected areas such as the Hutovo Blato wetland. The lack of scientific information is primarily associated with a lack of targeted research, since gobies are easily overlooked due to their small size and lack of commercial value (Tutman et al. 2013). Furthermore, the effective implementation of appropriate and effective conservation measures is seriously hindered by the difficulty of species identification.

The present study exposes the extent of ignorance on the current status, distribution and impacts of gobies species in Bosnia and Herzegovina. These gaps should be addressed through coordinated research that could assist effective conservation efforts. Therefore, this study represents an impetus for gathering biological and ecological information, identifying threats and conservation challenges and in recognition of the gaps in our current knowledge. Future studies may reveal a larger distribution range for certain species, especially the invasive P-C gobies. The small karstic watercourses in the Adriatic basin, i.e. the Cetina sub-basin (Livanjsko Polje and Duvansko Polje) along the Croatian border will also be a challenge in future biodiversity research. Detailed studies are required to explain the taxonomic status of goby species in the lower Neretva River drainage. Although gobies have no economic value, they are significant for ichthyofauna conservation and overall fish diversity.

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