

SHORT COMMUNICATION

First record and evidence of an established population of the darter goby (*Ctenogobius boleosoma*) in the Adriatic Sea

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Abstract: Non-native species represent one of the major threats to the preservation of Mediterranean biodiversity, as a significant number of marine organisms colonize this region either by passing through the Suez Canal or *via* other vectors, such as marine traffic and ballast water. Fourteen non-native goby species have already been documented in the Mediterranean Sea, with their distribution currently being restricted to the Levantine Basin and Aegean Sea, in addition to a single record from the Ionian Sea. In contrast, no non-native species from this group have been recorded in the Adriatic Sea to date. This study documents both the first record and evidence of an established population of the darter goby (*Ctenogobius boleosoma*) in the southeastern Adriatic Sea (Montenegro), identified by genus and species diagnosis. Thirteen individuals were collected from the Jaz River between September and December 2025. The fin coloration pattern is described, including the unusual pectoral fin coloration for this species.

Keywords: Adriatic Sea; invasive species; first record; darter goby; Oxudercidae; Montenegro

Sažetak: PRVI NALAZ I DOKAZ O USPOSTAVLJENOJ POPULACIJI STRELIČASTOG GLAVOČA (*CTENOGOBIUS BOLEOSOMA*) U JADRANSKOM MORU. Strane vrste predstavljaju jednu od glavnih prijetnji očuvanju mediteranske raznolikosti, s obzirom na to da veliki broj morskih vrsta kolonizira ovo područje, prolazeći kroz Sueski kanal ili nekim drugim načinima kao što su unos pomorskim prometom i balastnim vodama. Četrnaest stranih vrsta glavoča je do sada već zabilježeno u Mediteranu te je njihova rasprostranjenost trenutno ograničena na Levantski zaljev i Egejsko more, uz jedan zabilježen nalaz u Jonskom moru. Nasuprot tome, u Jadranu do sada nisu pronađene strane vrste glavoča iz ove skupine. Ovaj rad bilježi prvi nalaz i uspostavljenu populaciju streličastog glavoča (*Ctenogobius boleosoma*) u jugoistočnom Jadranu (Crna Gora), identificirane na osnovi određivanja roda i vrste. Prikupljeno je trinaest jedinki iz rijeke Jaz u periodu od rujna do prosinca 2025. godine. Opisan je obrazac obojenosti peraja, uključujući i neuobičajenu obojenost prsnih peraja za ovu vrstu.

Ključne riječi: Jadransko more; invazivne vrste; prvi nalaz; glavoči; Oxudercidae; Crna Gora

INTRODUCTION

Non-native species represent one of the major threats to Mediterranean biodiversity, with 751 established non-native marine taxa recorded in the basin by December 2021; among these, fishes account for 173 validated non-native taxa, of which 97 are established species (Zenetos *et al.*, 2022). The majority of these species originate from the Indo-Pacific region and have entered the Mediterranean Sea *via* the Suez Canal, resulting in a pronounced accumulation of non-native species in the Levantine Basin due to its proximity to the canal and the subtropical temperature profile of the said basin (Galil, 2023). The ongoing warming of the Mediterranean Sea, along with intense maritime traffic, coastal habitat modification, and aquaculture-related activities, has further facilitated the introduction, establishment, and spread of numerous species throughout the rest of the Mediterranean Sea (Korpinen *et al.*, 2020).

Families Gobiidae and Oxudercidae, referred to as gobies, are large marine fish families comprising 2204

valid species, 1452 and 752, respectively (Fricke *et al.*, 2026). Gobies inhabit a wide range of aquatic environments, including marine, brackish, and freshwater habitats (Thacker and Roje, 2011). Gobies also represent the most speciose fish group in the Mediterranean Sea, where they are represented by a total of 78 species, of which 64 are native, and 14 are non-native (Kovačić *et al.*, 2022; Kovačić and Sacchetti, 2023; Kovačić, 2025). In the Adriatic Sea, gobies are also well represented, with 50 native species recorded to date (Kovačić *et al.*, 2020, 2021; Dulčić *et al.*, 2022; Kovačić and Froglija, 2023).

The darter goby, *Ctenogobius boleosoma* (Jordan & Gilbert, 1882), is a small goby species native to the western Atlantic, typically reaching a total length of 4-5 cm, and exhibiting clear sexual dimorphism. The species is characterized by a high degree of environmental tolerance, being euryhaline and capable of withstanding a wide range of salinity conditions, although it is most commonly associated with estuarine environments. Estuaries, coastal lagoons, and river mouths with predomi-

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nantly muddy substrates represent the primary habitats of adult individuals (Pezold, 2022; Campbell *et al.*, 2025). Along the Atlantic coast, *C. boleosoma* spawns during summer and autumn (Wyanski and Targett, 2000). The species' high dispersal potential is largely attributed to its planktonic larval stages, which are highly mobile and capable of long-distance transport (Gomes and Bonecker, 2014). This ecological flexibility during the larval stage, combined with broad salinity tolerance, likely contributes to the successful establishment and spread of *C. boleosoma* in newly colonized areas (Castro and Bonecker, 2017). Based on currently available records, *C. boleosoma* has been reported in the Mediterranean Sea from only three localities (Mavruk *et al.*, 2022; Kovačić and Sacchetti, 2023; Stern *et al.*, 2025) (Fig. 1).

The first record of *Ctenogobius boleosoma* in the Mediterranean Sea was confirmed through DNA barcoding of mesopelagic larval stages collected in Antalya Bay (Turkey) (Mavruk *et al.*, 2022). Subsequently, the presence of *C. boleosoma* at the mouth of the Agri River in southern Italy (Ionian Sea) was reported, where multiple individuals were collected (Kovačić and Sacchetti, 2023). The same authors concluded that the species has formed a stable population in the area, as indicated by the presence of multiple sexually mature individuals at the locality. The latest record of *C. boleosoma* was from an eDNA survey of the Na'aman River in Israel (Stern *et al.*, 2025). Although many non-native fish species have been recorded in the Adriatic Sea, there are currently no records of non-native goby species in this basin, apart from those recently described elsewhere in the Mediterranean (Dulčić and Dragičević, 2023). The aim of this study is to report the first record of the non-native goby species *C. boleosoma* in the Adriatic Sea and to document the presence of an established population in this part of the Mediterranean.

MATERIAL AND METHODS

The Jaz River (Montenegro, Adriatic Sea) is formed by the confluence of the Lukavica and Drenovštica rivers on the western slopes of Donja Gora (348 m above sea level). The flow occurs at approximately 5 m above sea level and flows through the Mrčevo Polje field before discharging into Jaz Bay. The river has a short course, extending approximately 2.5 km in length (Barović *et al.*, 2021).

A total of 13 individuals of *Ctenogobius boleosoma* were collected on two occasions using a hand net at the same locality (42°16'51.24" N, 18°47'58.92" E). The first specimen was recorded during the morning hours (10:00-11:00 A.M.) on 30 September 2025 at the Jaz River estuary, approximately 100 m upstream from the river mouth. Under favourable weather conditions (calm water and good visibility), the fish was noticeable due to its vivid coloration and active behaviour. The same locality was revisited on 19 December 2025, when 12 additional individuals were collected during night hours. Several other individuals were observed in the river but were not captured.

All collected individuals were transported to the Institute of Marine Biology - University of Montenegro, where they were fixed in 70% ethanol to ensure optimal preservation of diagnostic morphological characters. Individuals were examined under a Zeiss Stemi 508 stereomicroscope, and species identification was based on diagnostic traits following the descriptions provided by Pezold (2022). The terminology for head canal pores and gill morphology follows Pezold (2022). Preserved individuals were subsequently measured using a calliper (to the nearest 0.1 mm), and selected morphometric measurements were taken from all individuals following Pezold (2022). Individual weight was also recorded after preservation, with an accuracy of 0.01 g. The first

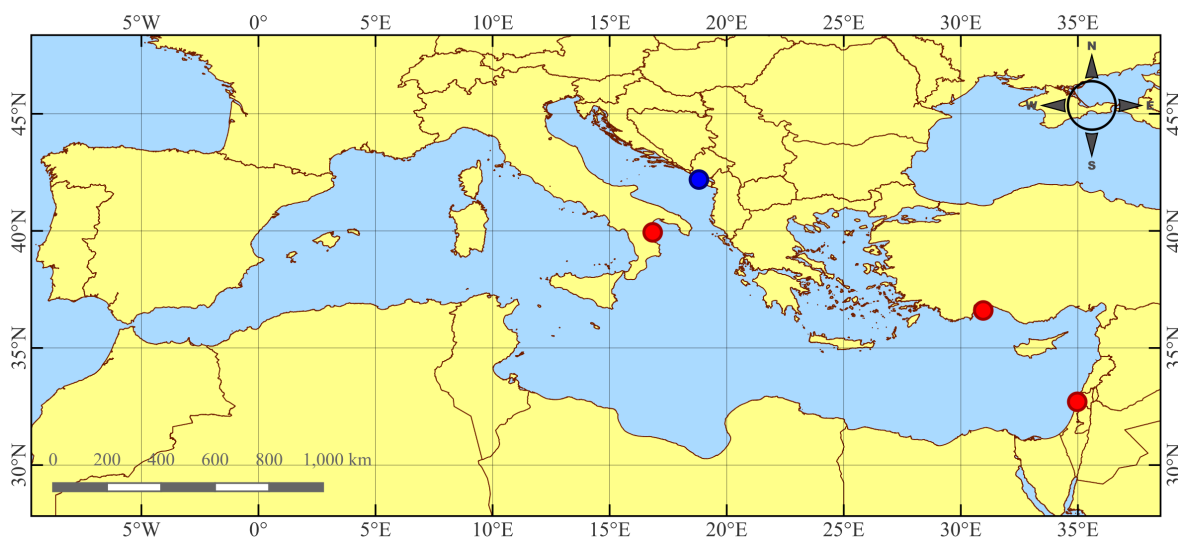


Fig. 1. Current records of the darter goby (*Ctenogobius boleosoma*) in the Mediterranean Sea. Previously published records are shown in red (Mavruk *et al.*, 2022; Kovačić and Sacchetti, 2023; Stern *et al.*, 2025), and the record from this study is shown in blue.

and largest specimen collected was deposited in the Institute's fish collection under ID number IBMK-FIS-WET-2025-0006.

RESULTS AND DISCUSSION

Collected individuals were identified as species belonging to the genus *Ctenogobius* based on the following diagnostic traits: i) one more ray in the anal fin than in the second dorsal fin; ii) absence of gill rakers or lobular structures on the epibranchial of the first gill arch, one triangular raker at the angle of the arch and three or four triangular rakers on the first ceratobranchial parallel to its axis; iii) head canals with an anterior oculoscapular canal with A'BCDFH' pores, no posterior oculoscapular canal and a preopercular canal with M'NO' pores (Kovačić

and Sacchetti, 2023). Species diagnosis: collected individuals were identified as *Ctenogobius boleosoma* based on the following diagnostic traits: i) the second dorsal fin comprising one spine and ten soft rays (I,10) (Fig. 2A, B), and the anal fin with one spine and eleven soft rays (I,11); ii) a distinct dark pigment posterodorsally to the operculum, above the base of the pectoral fin, forming a characteristic shoulder patch (Fig. 2B); iii) scales in lateral series 35 or fewer; iv) pectoral fins reaching the anus or the origin of the anal fin; v) absence of ocelli on the head or trunk; vi) a completely scaleless nape and absence of scales to the rear margin of the operculum; vii) non-elongated third dorsal fin spine; and viii) five mid-lateral dark blotches with dorsal extensions forming a distinct V-shaped pattern along the sides of the trunk, clearly visible in most individuals (Figs. 2A, 2B and 3).

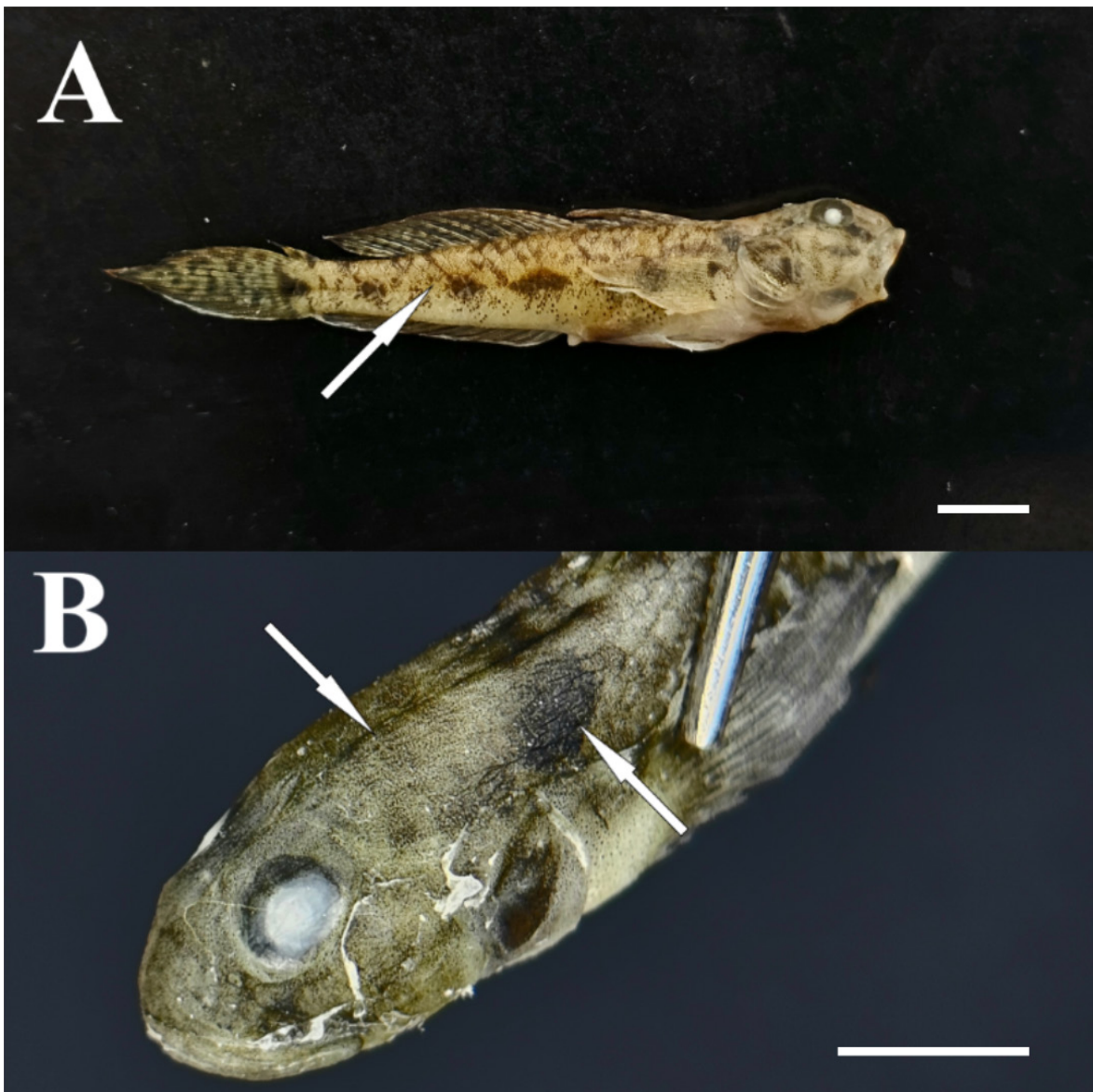


Fig. 2. Some diagnostic traits of *Ctenogobius boleosoma* from the Adriatic Sea: an individual showing distinct five lateral dark blotches, extending into a V-shaped pattern (**A**); scaleless nape and shoulder patch of pigment present (**B**). Scale bar 5 mm. (Photo credit: D. Marđokić).

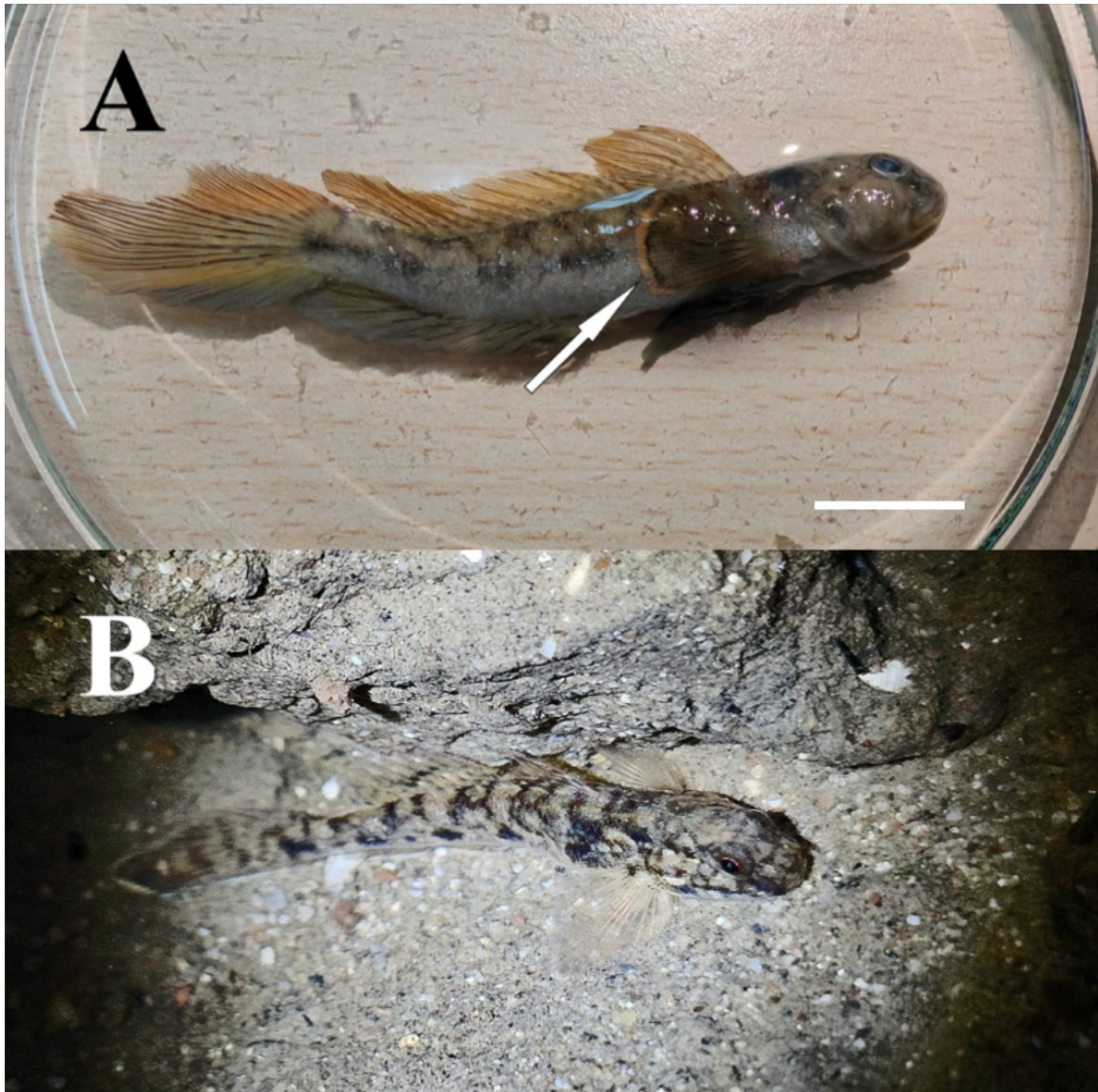


Fig. 3. *Ctenogobius boleosoma* from the Adriatic Sea: male showing distinct orange margin of the pectoral fin, scale bar 1 cm (**A**); female documented *in situ* in Jaz River during fieldwork (**B**). (Photo credits: I. Četković and D. Mardokić).

Of the 13 individuals collected, four were males, and the remaining nine were females. Standard length (SL), caudal fin length and weight of the examined specimens are as follows: specimen no. 1, female: 33.1 + 8.1 mm, 0.37 g; specimen no. 2, female: 29.3 + 7.7 mm, 0.28 g; specimen no. 3, female: 33.9 + 9.1 mm, 0.41 g; specimen no. 4, female: 31.4 + 8.1 mm, 0.35 g; specimen no. 5, female: 31.1 + 8.9 mm, 0.36 g; specimen no. 6, female: 30.9 + 10.1 mm, 0.36 g; specimen no. 7, female: 33.1 + 10.1 mm, 0.36 g; specimen no. 8, female: 27.9 + 8.6 mm, 0.24 g; specimen no. 9, female: 32.8 + 10.5 mm, 0.43 g; specimen no. 10, male: 28.8 + 9.0 mm, 0.21 g; specimen no. 11, male: 31.0 + 9.9 mm, 0.29 g; specimen no. 12, male: 32.9 + 12.8 mm, 0.36 g; specimen no. 13, male: 49.3 + 18.2 mm, 1.58 g. Caudal fin relatively longer in males (31.3–38.9% SL) than in females (26.3–

32.0% SL). Body slender, elongated, with a slightly compressed posterior part and a relatively narrow caudal peduncle, typical of small benthic gobies such as *Ctenogobius*. Preanal body length 50.8–55.3% of SL in females and 47.7–49.5% of SL in males, indicating a relatively longer anterior body region in females. Postanal body length 44.7–49.2% of SL in females and 50.5–52.3% of SL in males. Body depth 16.1–20.9% of SL in females and 14.6–17.6% of SL in males, females generally appearing more robust. Caudal peduncle moderately elongate, its length 14.5–17.8% of SL in females and 14.2–19.0% of SL in males, while caudal peduncle depth varies more in females (7.5–13.3% of SL) than in males (7.3–9.1% of SL).

Head of moderate size, slightly depressed, with gently rounded snout; head length 22.9–29.0% of SL in fe-

males and 24.5–27.1% of SL in males, without clear sexual difference, whereas head width is somewhat greater in females (16.2–19.7% of SL) than in males (14.0–18.8% of SL). Snout short in both sexes (3.9–6.7% of SL in females; 4.8–6.4% of SL in males). Jaws are slightly more developed in males (9.4–10.6% of SL) compared to females (7.3–9.2% of SL). Eyes relatively large and positioned dorsolaterally, orbit length 4.9–6.8% of SL in females and 5.7–7.6% of SL in males; nape length 14.2–22.0% of SL in females and 19.9–21.6% of SL in males. Cheek region moderately expanded, with males generally showing greater cheek depth (6.9–9.4% of SL) and width (9.7–11.0% of SL) than females (5.6–8.7% and 7.5–10.0% of SL, respectively). The interorbital region is narrow, 1.2–2.7% of SL in females and 2.1–2.9% of SL in males. Mean values are: preanal body length 51.8% SL, postanal body length 48.2% SL, body depth 18.0% SL, caudal peduncle length 16.0% SL, caudal peduncle depth 9.4% SL, head length 25.9% SL, head width 17.7% SL, snout length 5.7% SL, jaw length 8.8% SL, orbit length 6.3% SL, nape length 19.3% SL, cheek depth 7.5% SL, cheek width 9.4% SL and interorbital width 2.0% SL.

The coloration of the fins in the examined male individuals matched the descriptions provided by Pezold (2022), including: i) dorsal fins in males with reddish/orange hue especially towards the margin of the second dorsal fin; ii) rows of reddish brown spots, small dark spot at the tip of the first and/or second dorsal fin spine prominent in individuals; and iii) the caudal fin displaying bright orange-red coloration along the upper quarter, dark stripes parallel to the rays in its middle half, and a dusky coloration on the lower portion of the fin. In addition to the aforementioned color patterns, the largest collected individual, a male, exhibited one additional highly distinctive trait prior to preservation. Its pectoral fins were largely transparent but featured a distinctly pigmented margin, consisting of a thin black line followed by a vivid orange outer edge (Fig. 3A). Although Pezold (2022) provides detailed descriptions of coloration in both live and preserved specimens, this trait was not mentioned, nor has it been documented in other literature sources to the best of the authors' knowledge, but photos of *C. boleosoma* with an orange outer edge on the pectoral fin can be found published online (Robertson and Van Tassell, 2023).

An unidentified species of *Knipowitschia* was also observed at the sampling locality. Further surveys are needed to confirm its identity and to assess the local fish assemblage and potential interactions with *C. boleosoma*. Continued monitoring of this locality could provide a more detailed understanding of population dynamics and help determine the impact of *C. boleosoma* on native goby species, as well as on the entire biological community. The transitional waters are a rare habitat along the eastern Adriatic coast compared to the presence of marine coastal habitats; they are endangered in the Mediterranean by human-mediated disturbances and they are particularly vulnerable to biological invasions

(Zamora-Marín *et al.*, 2023).

To the best of our knowledge, this represents the northernmost published Mediterranean record of a non-native goby (Gobiidae *sensu lato*, Oxudercidae under current classification). It contributes to a better understanding of current distribution patterns and dispersal dynamics of non-native fish species in the region, providing valuable baseline information for future monitoring and management of marine biological invasions. This record of *C. boleosoma* also represents the first non-native goby species documented in the Adriatic Sea, thereby expanding the known diversity of this group in the basin (Kovačić *et al.*, 2012; Kovačić and Sacchetti, 2023). With the present record, the species richness of gobies in the Adriatic Sea increases to 51 species (see Introduction). Gobies are generally cryptic species and are frequently overlooked by both researchers and citizens, which likely explains why their range expansions often go undocumented and why available distribution data remain limited. Consequently, it is highly possible that other estuarine habitats in the Mediterranean and Adriatic Seas are already inhabited by this species. Among the goby species recorded in the Mediterranean Sea, *C. boleosoma* and *Tridentiger trignocephalus* (Gill, 1859) are native to temperate climates, giving them a greater potential to colonize cooler waters beyond the Levantine Basin, where most non-native goby species currently remain restricted (Kovačić and Sacchetti, 2023). While the majority of non-native goby species in the Mediterranean originate from the Indo-Pacific and are predominantly established in the warmer Levantine region, *C. boleosoma* is native to the western Atlantic, making its presence in the Mediterranean unusual. Although the exact introduction pathway remains uncertain, the transport of larval stages *via* ballast water represents a plausible vector (Mavruk *et al.*, 2022).

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