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Ctenogobius boleosoma (Jordan & Gilbert, 1882) (Gobiiformes: Gobiidae), the northwesternmost record of an alien goby in the Mediterranean Sea, and a review of Mediterranean alien gobies

Marcelo KOVAČIĆ[1] and Stefano SACCHETTI[2]

[1] Natural History Museum Rijeka, Lorenzov prolaz 1, HR-51000 Rijeka, Croatia
[2] Hydrosynergy soc. coop., Accredited Spin-off of the Alma Mater Studiorum, University of Bologna, Via Roma 11, IT-40068, San Lazzaro di Savena, Bologna, Italy

Corresponding author: Marcelo KOVAČIĆ; marcelo@prirodoslovni.com

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Abstract

The Western Atlantic goby *Ctenogobius boleosoma* (Jordan & Gilbert, 1882) was found at the Agri River mouth, south Italy. It is the northwesternmost record of an alien goby recorded in the Mediterranean Sea. The present record confirms the presence of *C. boleosoma* in the Mediterranean Sea, recently reported only by the DNA barcoding of larvae collected in the mesopelagic depths of the Levant Sea. The present record of adult individuals, including ripe females, indicates an established population present in shallow estuarine waters matching the species' native habitat conditions. The morphology and coloration of Mediterranean *C. boleosoma* are described and discussed. A detailed description of the cephalic lateral-line system of *C. boleosoma* is given for the first time. Ten species of the Mediterranean alien gobies are most likely Lessepsian migrants. Three gobiid aliens are Indo-Pacific gobies not present in the Red Sea and probably introduced by shipping. The alien gobies include only one Atlantic species and the Eastern Atlantic ingression component is lacking compared to the other alien fishes in the Mediterranean Sea. Indo-Pacific gobies have been quite successful in the colonization in Mediterranean and in the establishment of the Levant populations. However, contrary to other alien fishes, gobies show limited distribution across the Mediterranean Sea, with almost all alien gobies still being restricted to the Levant.

Keywords: *Ctenogobius boleosoma*; Mediterranean Sea; Gobiidae; alien species; adult stage; northwesternmost record.

Introduction

The family Gobiidae is the most speciose family of fishes in the Mediterranean Sea (Kovačić, 2020). Gobies are also the best represented fish family among alien fishes in the Mediterranean Sea, with 14 species in total (Özden *et al.*, 2022; Mavruk *et al.*, 2022). Among them, two species, *Hazeus ingressus* Engin, Larson & Erhan, 2018 and *Cryptocentrus steinhardti* Goren & Stern, 2021, were even described from the Mediterranean Sea. *Hazeus ingressus* and *C. steinhardti*, considering the geographic distribution of their genera, are obviously aliens in the Mediterranean, despite that they were found first in the Mediterranean Sea before any record in the native area (Engin *et al.*, 2018; Goren & Stern, 2021; Kovačić *et al.*, 2022). Most of the alien gobies in the Mediterranean Sea have a limited distribution to the Levant, although some of them have well-established populations there (Kovačić *et al.*, 2022). Among them, only *Oxyurichthys petersii* (Klunzinger, 1871) and *Vanderhorstia mertensi* Klausewitz, 1974 have expanded north from Levant to the Aegean Sea (Kovačić *et al.*, 2022) (Fig. 1).

Specimens of an unknown gobiid species were collected at Agri River mouth, south Italy, and were identified as the Western Atlantic goby *Ctenogobius boleosoma* (Jordan & Gilbert, 1882). *Ctenogobius boleosoma* was recently reported in the Mediterranean Sea only by the DNA barcoding of larvae collected by plankton net in an unusual habitat, at mesopelagic depths of 373 m and 1150 m (Mavruk *et al.*, 2022). The aims of this paper are 1) to report the northwesternmost alien goby presence in the Mediterranean Sea identified from morphology and coloration, 2) to provide a detailed description and illustration of the cephalic sensory papillae of *C. boleosoma*, and 3) to review the distribution of alien Gobiidae in the Mediterranean Sea.

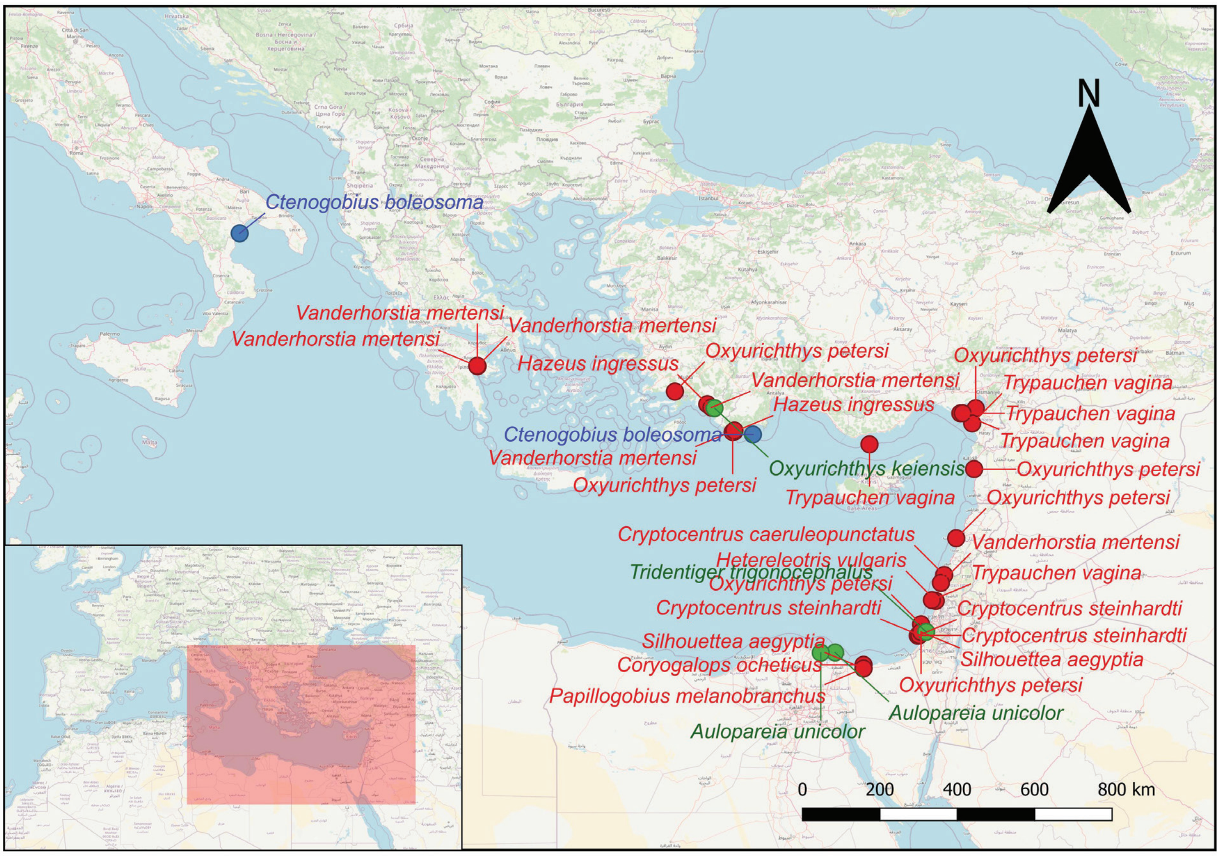

Fig. 1: The distribution of alien gobies in the Mediterranean: (●) Western Atlantic origin; (●) Indo-Pacific origin, native to the Red Sea, probably Lessepsian; (●) Indo-Pacific origin, not native to the Red Sea, probable vector shipping. The individual record data and the references are in Table 1.

Material and Methods

Specimens were caught during daylight on 14 September 2021 at Agri River mouth, along muddy banks, approximaly 1 km upstream from the Ionian Sea. The sampling was performed by electrofishing (100-400 V, 1-6 A, DC) from boat. The sampling was part of the "BLUE CRAB" project (FEAMP PO 2014–2020 promoted by Basilicata Region, Italy) fish monitoring activities. The project collected data on the invasive brachyuran *Callinectes sapidus* and its habitat with the aim of controlling the spread and facilitating management of this species.

Specimens were fixed in 70% ethanol solution for morphological analysis. The terminology and the format style of rows of cephalic sensory papillae followed Sanzo (1911) and Miller (1986) and those of the head canal pores followed Pezold (2022). Morphometric and meristic methods followed methodology in Pezold (1991; 2022). Measurements smaller than 20 mm were taken with interactively selected points in Olympus cellSens Entry 2.2 software using an Olympus SC180 camera and Olympus U-TV0.5XC-3 camera adapter on an Olympus SZX10 stereomicroscope. Measurements >20 mm were taken by digital caliper (i.e. direct point to point measurements). Specimen length is presented as the standard length (SL) + caudal-fin length. The material was stained in 2% solution of Cyanine Blue in distilled water (Saruwatari *et al.*, 1997) for studying scales and head lateral-line system. Helicon Focus 7.0.2 was used, when necessary, for focus stacking software to reach acceptably sharp microphotography from combined images. Specimens were diagnosed using combinations of characters derived from Jordan & Gilbert (1882) and Pezold (2004; 2022). The material was deposited in the Prirodoslovni muzej Rijeka (PMR).

Results

Studied material. Male, 27.7+9.92 mm, PMR VP5373. Male, 27.54+10.82 mm, PMR VP5374. Female, 23.03 mm, caudal fin tips damaged, PMR VP5382. Male, 28.51 mm, caudal fin tips damaged, PMR VP5375. Male, 30.19+11.88 mm, PMR VP5376. Male, 26.5+9.08 mm, PMR VP5377. Female, 21.61+7.1 mm, PMR VP5378. Female, 25.69 mm, caudal fin tips damaged, PMR VP5383. Male, 30.79+12.02 mm, PMR VP5379. Female, 32.05+10.12 mm, PMR VP5380. Female, 25.5+8.22 mm, PMR VP5381. All material from South Italy, Agri river, 40.218047°N 16.727873°E, collected on 14 September 2021 by Hydrosynergy S.C. (Gianluca Zuffi, Andrea Marchi, Stefano Sacchetti, Matteo Nanetti).

Identification. Genus diagnosis. 1) One more ray in the anal fin than in the second dorsal fin. 2) No 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 (Fig. 2). 3) Head canals with anterior oculoscapular canal with A'BCDFH' pores, no posterior oculoscapular canal and preopercular canal with M'NO' pores (Fig. 3).

Species diagnosis. 1) Second dorsal fin elements and anal fin elements I,10 and I,11. 2) Dark patch of pigment posterodorsal to opercle above pectoral fin base (shoulder patch) present (not visible in almost completely pale specimens PMR VP5378 and PMR VP5382. 3) Pectoral fins reaching anus or anal fin origin. 4) Lateral scales 29-35 (29-34 in present specimens). 5) Nape naked or with few scales, not scaled to rear margin of opercle (naked in present specimens except PMR VP5374 and PMR VP5380 with a few scales). 6) Third spine of first dorsal fin not elongate. 7) Dorsal extensions of midlateral blotches forming V pattern on sides of trunk (V pattern visible in about half of the preserved specimens).

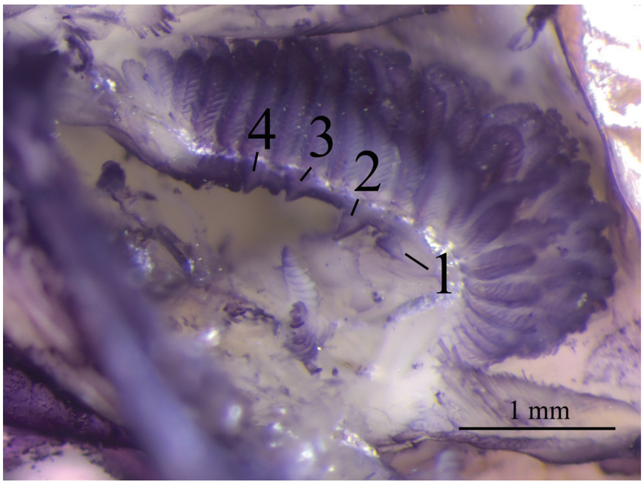

Fig. 2: *Ctenogobius boleosoma.* Female, 23.03 mm, caudal fin tips damaged, PMR VP5382, view from ventral side: no gill rakers or lobular structures on the epibranchial of the first gill arch, one triangular raker at the angle of the arch (marked 1) and three triangular rakers on the first ceratobranchial parallel to its axis (marked 2-4). Photo credit: M. Kovačić, produced by focus stacking.

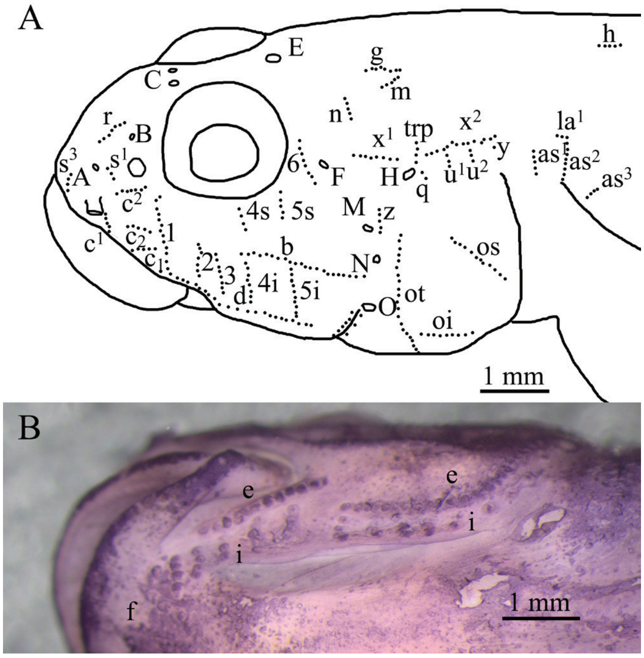

Fig. 3: Head lateral-line system with canals and sensory papillae of *Ctenogobius boleosoma.* Female, 25.69 mm, caudal fin tips damaged, PMR VP5383, South Italy, Basilicata region, Agri River mouth, approximately 1 km upstream of Ionian Sea. (A) Dorsolateral view. (B) Ventral view. The head canals with anterior oculoscapular canal with A'BCDFH' pores, no posterior oculoscapular canal and preopercular canal with M'NO' pores. Terminology of sensory papillae rows in text. Drawing and Photo credit: M. Kovačić.

Description of present specimens (Fig. 4). Body moderately elongate, laterally compressed posteriorly, preanal body length 45.6-51.8% of SL in males, 51.7-54.7% of SL in females, postanal body length 48.2-54.4% of SL in males, 45.3-48.3% of SL in females, body depth 18.5-19.5% of SL in males, 18.7-21.3% of SL in females (the largest values were in ripe females with visible eggs in belly). Caudal peduncle length 13.6-16.7% of SL, depth 8.8-10.4% of SL. Head moderately large, about cylindrical, head length 24.6-29.31% of SL, head width 17.9-22.1% of SL. Snout rounded, snout length 6.0-8.8% of SL. Subterminal mouth very slightly oblique, jaw length 10.8-12.2% of SL in males, 8.6-9.5% of SL in females. Premaxilla protractile. Eyes large, orbit length 5.8-7.4% of SL in males, 6.2-7.7% of SL in females, dorsally forming head dorsal profile. Cheek depth 8.1-10.0% of SL, cheek width 8.1-9.0% of SL in males, 8.6-9.1% of SL in females. Interorbital narrow, interorbital width 1.7-2.7% of SL. No fleshy crest on nape, nape length 19.8-22.5% of SL in males, nape length 21.7-22.7% of SL in females. Anterior nostril nasal tube without process from rim, posterior nostril a flat pore. Branchiostegal membranes fused to isthmus along the entire lateral margin of the isthmus, from immediately anterior to pectoral margin.

Fins. First dorsal fin VI; second dorsal fin elements I,10; anal fin I,11; segmented caudal rays 12-16; pectoral fin 16-17, pelvic fin I+5; branched caudal rays 14-16. First dorsal fin spines not elongate, 3rd, 4th or 5th spine of males reaching 2nd or 3rd element of second dorsal fin when folded down, 3rd or 4th spine of females barely

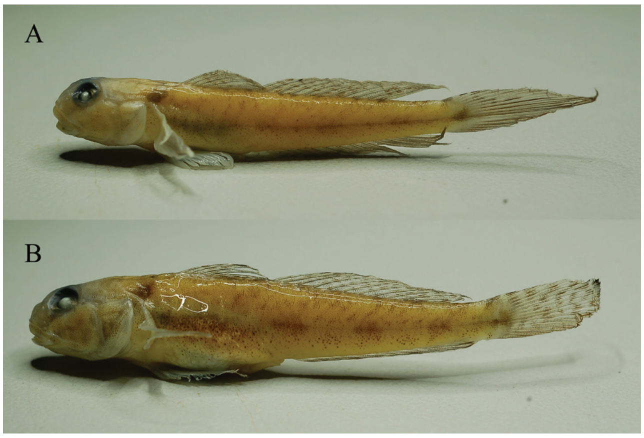

Fig. 4: *Ctenogobius boleosoma.* (A) Male, 27.7+9.92 mm, PMR VP5373, (B) Female, 32.05+10.12 mm, PMR VP5378. South Italy, Basilicata region, Agri River mouth, approximately 1 km upstream of Ionian Sea. Photos credit: M. Kovačić.

reaching the dorsal spine of second dorsal fin. Pectoral fins reaching or nearly reaching to vertical through anal fin origin in males and a vertical through anus in females, pectoral fin length 20.5-23.0% of SL. Pelvic fin extending to urogenital papilla in males, not reaching anus in females, pelvic fin length 22.9-25.7% of SL in males, 20.5-22.9% of SL in females. Pelvic fins forming disc, rounded, complete, pelvic anterior membrane well-developed and with crenate edge in females, with villose edge in males. Caudal fin longer than head, lanceolate and longer in males than females, caudal fin length 34.3-39.4% of SL in males, 31.6-32.9% of SL in females.

Scales. Body with ctenoid scales, except cycloid on belly. No scales on head and nape except in PMR VP5374 and PMR VP5380 small cycloid scales in 2 and 4 transversal rows, respectively, in front of the first dorsal fin spine. Prepectoral and breast naked. Belly with cycloid scales, but naked behind pelvic fin origin. Small cycloid scales along the anterior edge of the scaled dorsum, extending from behind upper part of pectoral axilla backward and up to the first dorsal-fin spine. The base of dorsal fins scaled. Lateral scale count 29-34. Transverse forward scale count 10-12. Transverse rearward scale count 8-11. Circumpeduncular scale count 11-12, lateral peduncular scale count 6-7.

Head lateral-line system (Fig. 3). Head canals with anterior oculoscapular canal and preopercular canal, posterior oculoscapular canal absent. Anterior oculoscapular canal with 11 pores: a pair of anterior nasal pores *A'*, a pair of posterior nasal pores *B*, a pair of anterior interorbital pores *C*, a single posterior interorbital pore *D*, and paired pores *F* and *H'* (anterior otic pore and terminal intertemporal pore, respectively) Preopercular canal with three pores: *M'NO'* pores. Rows of sensory papillae: *Preorbital*: median series in three rows: row *r* (5-8 papillae) as single longitudinal row median to pore *B*; row s^1 (3-4) as short transverse row below posterior nostril; row s^2 not visible, row s^3 (3-4) above lip, longitudinal row median to pore *A'*, reaching near to upper lip; lateral series in four rows: row c^2 (5-7) as one longitudinal to oblique row between the anterior and posterior nostrils; row c^1 (4-5) as vertical row at anterior nostril base, row c_2 (5-7) horizontal above row c_1, row c_1 (3-7) horizontal row above upper lip, both ending posteriorly at row *1*. *Suborbital*: Two longitudinal (*b, d*) rows on cheek, no longitudinal row *a*. Suborbital longitudinal row *b* (20-26) long, anteriorly ending at row *4* below posterior pupil, and posteriorly reaching edge of preopercle and the preopercular canal. Five main transverse rows on cheek (*1–5*) with rows *4* and *5* divided into superior and inferior rows (labelled *4s, 5s* and *4i, 5i,* respectively) above and below row *b* (*1:* 12-16, *2:* 5-7, *3:* 7-10, *4:* 4+8 to 12+8, *5:* 6+9 to 5+14), one more row *6* (4-8) present as row in front of pore *F*. Suborbital longitudinal row *d* (24-35) long, from above posterior part of upper lip to behind vertical of posterior eye edge. *Preoperculo-mandibular*: External row *e* (12+28 to 18+35) as single row, divided behind angle of jaw. Internal row *i* also divided, but papillae proliferated in short transverse rows, mostly in the anterior part, anterior transverse rows of 2-5 papillae, while posteriorly papillae single to tripled, row *i* with 6+9 to 7+10 transverse rows, ending anteriorly as a few perpendicular rows to row *f*. Mental row *f* (7-10) longitudinal. *Oculoscapular*: Anterior longitudinal row x^1 (7-12) and posterior longitudinal row x^2 (10-16) long, separated by transverse row *trp* (3-5). Transverse row *z* (3-7) behind pore M'. Row *q* (2-3) as transverse row behind pore pore *H'*. Two more transverse rows, each of 2-3 papillae, below row x^2, placed on the position of the missing posterior oculoscapular canal, tentatively named u^1 and u^2. Row *y* as single papilla below posterior end of row x^2. Transverse axillary rows as^1 (5-8), as^2 (5-8), as^3 (4-10), longitudinal axillary row la^1 (3-8) above row as^2, longitudinal axillary row la^2 (4-8) above row as^3, both not observed in most of the material. *Opercular*: Transversal row *ot* (22-30); longitudinal superior row *os* (10-12) oblique, descending backwards; longitudinal inferior row *oi* (9-11) horizontal. *Anterior-dorsal:* Transversal row *n* (4-6) behind eye, short. Transversal row *o* absent. Longitudinal row *g* (5-8) distant from row *n*. Longitudinal row *m* (3-5) oblique to horizontal, below longitudinal row *g*. Longitudinal row *h* (5-14) in front of first dorsal fin base.

Preserved color (Fig. 4). Head and body of preserved specimens yellowish to fawn, with brown markings. Some of the specimens of both sexes were paler and with very little pigmentation. Body with brown reticulate pattern following scale edges on the upper half. Lateral midline with four oblong poorly defined spots, longitudinally elongated and with triangular mark with anterior tip at caudal fin base. The scale edge pigmentation forms poorly visible anterodorsal and posterodorsal diagonal bars arising from three midlateral blotches, not visible in all specimens. These dorsal extensions of midlateral blotches form a V pattern on sides of the trunk in about half of the present specimens. Scattered melanophores present also below midline. Brown stripe extending forward from orbit to mid-jaw more or less visible. Opercle dusky. Large dark shoulder patch posterodorsal to opercle above pectoral fin base present (not visible in almost completely pale specimens PMR VP5378 and PMR VP5382). Diagonal bars on the first dorsal fin, less prominent on the second dorsal fin. Anal fin dusky in males with occasional dark spots near base; dark submarginal bar on transparent fin in females. Pectoral fin transparent and rarely dotted in females. Pectoral fin in males dusky with whitish marginal mark at fin tips of central rays. Pelvic fins dusky in adult males, with white streak between fifth rays in proximal half. In females, additionally, lateral third of fin also whitish. Caudal fin in males with a clear streak near upper edge, variably visible dark longitudinal stripes parallel to rays in middle half; ventral part of fin mostly dusky. Caudal fin in females with brown vertical irregular bars.

Freshly collected color (Fig. 5). Specimens in photo (Fig. 5) quite pale, probably due to exposure to direct sunlight on whitish background, but still matching in general the species' live coloration (see Robertson & Van Tassell, 2019). Body beige, light tan to olive on upper half, cream below lateral midline (more visible on upper left specimen in Fig. 5). Brown patch above pectoral fin base extending to nape (more visible in specimens on the

Fig. 5: *Ctenogobius boleosoma.* Coloration of freshly collected specimens, composite of several photos. The individuals on the photos belong to the listed studied material, but from the photos they cannot be assign to match particular specimens in the list of studied material. The original photo of the lower right fish was without ichthyometer included. South Italy, Basilicata region, Agri River mouth, approximately 1 km upstream of Ionian Sea. Photo credit: S. Sacchetti.

right in Fig. 5). Brown spots along dorsal midline (more visible at dorsal fin base e.g. on upper left specimen in Fig. 5). Head beige, mottled brown, with more or less visible brown stripe extending forward from orbit to midjaw. Dorsal fins in males with reddish to orange hue, especially at posterior margin of second dorsal fin (visible in males on the bottom of the Fig. 5). Dorsal fins otherwise with rows of brown spots. Anal fin in males dusky, females with narrow dusky longitudinal band at distal part of the anal fin. Caudal fin in males bright orange red along upper quarter and dark longitudinal stripes parallel to rays in middle half of fin; lower portion dusky (top and bottom specimens on Fig. 5). Caudal fin in females with vertical rows of dots, the left middle specimen on Fig. 5 with upper distal of caudal fin with dark mark, the right middle specimen with orange reddish upper part on Fig. 5.

Remarks. The present material fits in the general morphology and morphometry of *C. boleosoma* in Pezold (2022). Exceptions are the lower range values of males and females for the postanal length and the upper range value of maximum body depth in females, the latter caused by swollen bellies in ripe females in the present sample. The material also matches *C. boleosoma* fin and scale characters, including meristics, as described in Pezold (2022). The cephalic sensory papillae system is now fully described for the first time for *C. boleosoma.* Miller & Wongrat (1979) illustrated sensory papillae from a female specimen of *C. boleosoma* from Biloxi, Mississippi, USA. Their illustration was focused on comparisons of suborbital, cheek, preopercular – mandibular, and opercular series and omitted information on other series. The illustration was based upon a single specimen and also did not offer the degree of detail presented here. The lateral line system of present *C. boleosoma* material matches the general pattern in *Ctenogobius* genus, as illustrated on Figure 1 in Pezold (2022). In addition, the present data are the first application of complete Sanzo's (1911) nomenclature to any *Ctenogobius* species. The coloration of preserved specimens (Fig. 4) was less prominent than described pigmentation of preserved specimens in Pezold (2022), but matching the pattern. Also, the coloration of present preserved specimens, despite being less intense than live or freshly dead coloration, matches the pattern of live and freshly dead *C. boleosoma* photos in Robertson & Van Tassell (2019). Furthermore, some of the photos used by Robertson & Van Tassell (2019) were enhanced by the photographers (F. Pezold, personal communication). The freshly collected coloration of present specimens (Fig. 5) matches the coloration in life as described in Pezold (2022), except being to some degree less intense in some parts.

Distribution and ecology. Specimens were collected in the Agri River mouth (Basilicata region, south Italy, 40.218047°N 16.727873°E), downstream of Policoro, approximately 1 km far from Ionian Sea. The sampling site is characterized by fine-grained sediments (clays, silt, sand), slow current, high turbidity and salinity that usually ranges between 1-15 PSU, depending on the tidal flow. Most of the specimens were captured near the shoreline from 0.2 m to 0.5 m depth in open areas of fine muddy bottoms near *Phragmites* patches. Some females had enlarged belly with visible eggs inside (e.g. PMR VP5382) indicating ripe females and spawning season.

Discussion

The finding of an established and abundant population with the evidence of local reproduction of an alien fish species just recently recorded for the Mediterranean (Mavruk *et al.*, 2022) could be surprising. However, most gobies are small cryptic species that are usually not of interest to recreational or professional fishers and escape typical fishing gears. Many southern Mediterranean regions, like southern Italy, are lacking or deficient in ichthyological surveys and fish community data. Even ichthyologists, in published studies of coastal fish assemblages, have rarely or roughly reported gobiid species, with gobies generally remaining unidentified as Gobiidae indet. or *Gobius* sp. (Kovačić *et al*., 2022). The present record shows the importance of collecting accurate ichthyological data, especially considering climate change and the constant arrival of new alien species.

The thirteen alien gobiid species with already published records in the Mediterranean Sea are all Indo-Pacific species (Table 1). They were reported from the Levant (Fig. 1, Table 2 and reference therein). Only two species have additional records extending outside of the Levant in the Aegean Sea, *Oxyurichthys petersii* and *Vanderhorstia mertensi* (Kovačić *et al.*, 2022) (Fig. 1, Table 2).

Table 1. The list of alien gobies in the Mediterranean with native geographic distribution, habitat and temperature zone preferences. Native distribution by Froese & Pauly (2022), except * from Kovačić *et al.* (2022). Native area, habitat, and temperature zone by Froese & Pauly (2022).

Species	Native distribution	Native area	Habitat	Temperature zone	Vector of introduction
Aulopareia unicolor (Valenciennes, 1837)	China, Hong Kong, Indonesia, Singapore, Thailand, Vietnam	Western Pacific, Maritime Southeast Asia	Brackish	Tropical	Ships
Coryogalops ocheticus (Norman, 1927)	Red Sea and the Suez Canal to Port Said, Egypt (immigrant from Red Sea).	Western Indian Ocean	Marine	Tropical	Lessepsian
Cryptocentrus caeruleopunctatus (Rüppell 1830)	Red Sea	Western Indian Ocean	Marine	Tropical	Lessepsian
Cryptocentrus steinhardti Goren & Stern, 2021	Red Sea at Eilat, Israel*	Western Indian Ocean	Marine	Tropical	Lessepsian
Ctenogobius boleosoma (Jordan & Gilbert, 1882)	From New Jersey state in the USA on north to Rio Grande do Sul state in Brasil	Western Atlantic	Marine, brackish, freshwater	Temperate and tropical	Ships
Hazeus ingressus Engin, Larson & Erhan, 2018	Red Sea, Abu Dabab lagoon, Marsa Alam, Egypt*	Western Indian Ocean	marine	Tropical	Lessepsian
Hetereleotris vulgaris (Klunzinger, 1871)	Red Sea, Djibouti, Mozambique, southern Oman, and Pakistan	Western Indian Ocean	Marine	Tropical	Lessepsian
Oxyurichthys keiensis (Smith, 1938)	Western Indian Ocean: Inhaca, Mozambique to the Fish River mouth, South Africa; including Seychelles and Madagascar.	Western Indian Ocean	Brackish	Tropical	Ships
Oxyurichthys petersii (Klunzinger, 1871)	Red Sea	Western Indian Ocean	Marine	Tropical	Lessepsian
Papillogobius melanobranchus (Fowler, 1934)	Indo-West Pacific, including Red Sea	Indo-West Pacific	Marine, brackish	Tropical	Lessepsian
Silhouettea aegyptia (Chabanaud, 1933)	Red Sea	Western Indian Ocean	Marine	Tropical	Lessepsian
Tridentiger trigonocephalus (Gill, 1859)	South and East China, Yellow Sea and the Sea of Japan, Pacific coasts of Japan and the Philippines. Chromi Inlet in the Amur Estuary, Novgorodskaya Cove in the Bay of Pos'ete, and into the mouths and lower reaches of rivers running into Peter the Great Bay and into Amur Bay in Russia	Western Pacific	Marine, brackish, freshwater	Temperate	Ships
Trypauchen vagina (Bloch & Schneider, 1801)	Red Sea, India through the Malay Archipelago to China; Philippines; New Caledonia; South Africa	Indo-Pacific	Marine, brackish	Tropical	Lessepsian
Vanderhorstia mertensi Klausewitz, 1974	Red Sea, Japan, Papua New Guinea and the Great Barrier Reef	Indo-West Pacific	Marine	Tropical	Lessepsian

Table 2. The list of published alien gobies records with localities in the Mediterranean.

Species	Locality	Coordinates	Habitat	Reference
Aulopareia unicolor (Valenciennes, 1837)	Port Said, Egypt	31º 22’ 21.43’’N, 32 º 15’ 35.84’’E	15-20 m, no data on the bottom substrate	Akel & Rizkalla (2017)
Aulopareia unicolor (Valenciennes, 1837)	off Damietta, Egypt	31º 32’ 64’’N, 31º 53’ 08’’E	50 m, no data on the bottom substrate	Akel & Rizkalla (2017)
Coryogalops ocheticus (Norman, 1927)	Bardawil Lagoon, Northern Sinai, Egypt	no data	lagoon, soft bottom	Kovačić & Golani (2007)
Cryptocentrus caeruleopunctatus (Rüppell 1830)	Rosh Ha’nikra Achziv Nature Reserve, Israel	33º 04′ 59″N, 35º 06′ 10″E	20-30 m, soft-bottom habitats	Rothman & Goren (2015)
Cryptocentrus steinhardti Goren & Stern, 2021	Ashdod, Israel	31° 44’ 50.1’’N, 34° 24’ 47.22’’E	during the night and at depths of 60 to 80 m, no data on the bottom substrate	Goren & Stern (2021)
Cryptocentrus steinhardti Goren & Stern, 2021	Ashdod, Israel	31° 45’ 12.12’’N, 34° 27’ 02.16’’E	during the night and at depths of 60 to 80 m, no data on th e bottom substrate	Goren & Stern (2021)
Cryptocentrus steinhardti Goren & Stern, 2021	Ashdod, Israel	31° 45’ 35.34’’N, 34° 27’ 16.92’’E	during the night and at depths of 60 to 80 m, no data on the bottom substrate	Goren & Stern (2021)
Ctenogobius boleosoma (Jordan & Gilbert 1882)	Antalya Bay, Turkey	36.6°N, 30.7°E and 36.6°N, 30.8°E	Plankton net at the water depths of 1150 m and 373 m	Mavruk *et al.* (2022)
Hazeus ingressus Engin, Larson & Erhan, 2018	Fethiye Bay, Turkey	36° 44’ 05’’N, 28° 55’ 37’’E	15 m, soft bottom vegetated by the Lessepsian seagrass *Halophila stipula* (Forsskål) Ascherson, 1867	Engin *et al.* (2018)
Hazeus ingressus Engin, Larson & Erhan, 2018	Fethiye Bay, Turkey	36° 09’ 31’’N, 29° 37’ 53’’E	37 m, soft bottom vegetated by the Lessepsian seagrass *Halophila stipula* (Forsskål) Ascherson, 1867	Engin *et al.* (2018)
Hetereleotris vulgaris (Klunzinger, 1871)	Caesarae, Israel	no data	no data on the depth and bottom substrate	Hoese (1986)
Oxyurichthys keiensis (Smith, 1938)	Fethiye Bay, Turkey	36° 39’ 11.99’’N, 29° 06’ 55.01’’E	0-2 m depth in the mouth of the creek	Özden *et al.* (2022)
Oxyurichthys petersii (Klunzinger, 1871)	Kastellorizo Island, Greece	36° 09’ 0.9’’N, 29° 35’ 21.62’’E	2 m, on a muddy substrate	Apostolopoulos & Karachle 2016
Oxyurichthys petersii (Klunzinger, 1871)	Ashdod, Israel	no data	35-45 m, soft bottom	Ben-Tuvia (1983)
Oxyurichthys petersii (Klunzinger, 1871)	Tel Aviv, Israel	no data	35-45 m, soft bottom	Ben-Tuvia (1983)
Oxyurichthys petersii (Klunzinger, 1871)	Beirut, Batroun and Tripoli, Lebanon	no data	fish market, no data on the depth and bottom substrate	Fanelli *et al.* (2015)
Oxyurichthys petersii (Klunzinger, 1871)	Jableh, 25 kn south of Lattaquie, Syria	no data	50 m, sandy-muddy bottom	Saad & Sbaihi (1995)

Continued

Table 2 continued

Species	Locality	Coordinates	Habitat	Reference
Oxyurichthys petersii (Klunzinger, 1871)	Mersin Bay, Turkey	36° 39’ 0’’N, 34° 55-56’ 0’’E	22-4 m, sandy-muddy bottom	Kaya *et al.* (1992)
Oxyurichthys petersii (Klunzinger, 1871)	Gököva Bay, Turkey	no data	35 m, sandy bottom	Akyol *et al.* (2006)
Papillogobius melanobranchus (Fowler, 1934)	Bardawil Lagoon, Northern Sinai, Egypt	no data	lagoon, soft bottom	Kovačić & Golani (2007)
Silhouettea aegyptia (Chabanaud, 1933)	Bardawil Lagoon, Northern Sinai, Egypt	no data	lagoon, soft bottom	Miller & Fouda (1986)
Silhouettea aegyptia (Chabanaud, 1933)	Ashdod, Israel	no data	no data	Golani (1998) and personal communication
Tridentiger trigonocephalus (Gill, 1859)	Ashdod, Israel	31º 49’ 55.03’’N, 34º 38’ 13.12’’E	4-5 m, around the chain that anchors fish cages	Goren *et al.* (2009)
Trypauchen vagina (Bloch & Schneider, 1801)	Konacik, Arsuz coast, Turkey	no data	30 m, sandy muddy	Ergüden *et al.* (2018)
Trypauchen vagina (Bloch & Schneider, 1801)	Iskenderun Bay, Turkey	36° 32’ 40’’N 35° 31’ 27’’E	20-27 m, no data on the bottom substrate	Akamca *et al.* (2011)
Trypauchen vagina (Bloch & Schneider, 1801)	Iskenderun Bay, Turkey	36° 32’ 45’’N 35° 35’ 04’’E	20-27 m, no data on the bottom substrate	Akamca *et al.* (2011)
Trypauchen vagina (Bloch & Schneider, 1801)	Mersin Bay, Turkey	35° 53′ 28″N, 33° 09′19″E	25-30 m, no data on the bottom substrate	Yaglioglu *et al.* in Siokou *et al.* (2013)
Trypauchen vagina (Bloch & Schneider, 1801)	between Atlit and Hadera, Israel	no data	90 m, silty substrate	Salameh *et al.* (2010)
Vanderhorstia mertensi Klausewitz, 1974	Kondyli, Greece	37º 31’ 24.89’’N, 22º 56’ 8,38’’E	2-4 m, sandy, partially covered by *Cymodocea nodosa*	Tiralongo & Pillon (2019)
Vanderhorstia mertensi Klausewitz, 1974	Kondyli, Greece	37º 31’ 34.39’’N, 22º 56’ 18.71’’E	2-4 m, sandy, partially covered by *Cymodocea nodosa*	Tiralongo & Pillon (2019)
Vanderhorstia mertensi Klausewitz, 1974	Kondyli, Greece	37º 32’ 1.82’’N, 22º 55’ 50.63’’E	2-4 m, sandy, partially covered by *Cymodocea nodosa*	Tiralongo & Pillon (2019)
Vanderhorstia mertensi Klausewitz, 1974	Haifa Bay, Israel	32° 54’ 37.92’’N, 35° 01’ 02.04’’E	30 m, no data on the bottom substrate	Goren *et al.* (2013)
Vanderhorstia mertensi Klausewitz, 1974	Fethiye Bay, Trukey	36° 39’ 59’’N, 29° 02’ 06’’E	23 m, muddy sand	Bilecenoğlu *et al.* (2008)
Vanderhorstia mertensi Klausewitz, 1974	Kas, Antalya. Turkey	no data	8-15 m, sand	Yokes *et al.* (2009)

The presence of *O. petersii* was wrongly cited for Tunisia by Kovačić *et al.* (2022). The Mediterranean distribution of *O. petersii* was reported as being restricted only to the Levant in Golani *et al.* (2002). An additional Mediterranean record of alien goby that can be rejected is the record of *Silhouettea aegyptia* (Chabanaud, 1933) for Syria. Ali (2018) cited a Syrian record from an unpublished MSc thesis reviewing marine teleost fishes of Syria, which is grey literature with no provided evidence. *S. aegyptia* was also reported for the first time for Israel by Golani (1998) without details and Israel was not among localities of material of *S. aegyptia* used in the Miller & Fouda (1986) study. However that record from Israel can be considered positive since it was based on a specimen from Ashdod (HUJ 19235) identified by P.J. Miller in the collection of the Hebrew University of Jerusalem (D. Golani, personal communication) (Table 2).

Ten of the fourteen presently known Mediterranean alien gobies are marine or marine to brackish fishes native to the Red Sea, arriving in the Mediterranean Sea most likely as Lessepsian migrants, so the species entry point into Mediterranean Sea would have been in the Levant (Table 1). Two more gobiid aliens are tropical fishes with brackish water occurrence, not present in the Red Sea and probably with shipping as the vector of unintentional species introduction in the Mediterranean Sea (Table 1). The restriction of these twelve already recorded Mediterranean alien gobies to the Levant, with extension only to nearby Aegean Sea for only two species, is more likely the result of their ecological limits than the result of the entry point site (Fig. 1, Tables 1 and 2). Almost all of these gobies are exclusively tropical species, so the warm-temperate Mediterranean Sea with subtropical conditions is probably more suitable for them than the rest of the Mediterranean (Table 1). Among alien gobiid fishes in the Mediterranean Sea of the Indo-Pacific origin, only *Tridentiger trigonocephalus* (Gill, 1859) is a temperate species and its limitation in the Mediterranean presence to the Levant is therefore puzzling. Shipping as the vector is the most likely explanation also for this species, since its Lessepsian origin is excluded (Table 1). Contrary to all previous Mediterranean alien gobies, the Italian locality where *C. boleosoma* is recorded does not belong to the warmest parts of the Mediterranean Sea (Fig. 1). The record is the northwesternmost alien goby presence in the Mediterranean Sea. This is not surprising, since the western Atlantic *C. boleosoma* is a widespread species, ranging from New Jersey state in the USA in the north to Rio Grande do Sul state in Brasil in the south, covering a wide range of tropical and warm temperate waters (Guimarães *et al.*, 2017; Pezold, 2022). It was recently collected in its native range in similar habitat conditions as the present record, inside the river estuary at 0.5 m depth (Guimarães *et al.*, 2017). More surprising are the circumstances of the first Mediterranean record of *C. boleosoma. Ctenogobius boleosoma* was recently reported in the Mediterranean Sea by the DNA barcoding of larvae collected by the plankton net at the mesopelagic depths of 373 m and 1150 m (Mavruk *et al.*, 2022).

Until the Mediterranean findings, *C. boleosoma* was restricted to the Western Atlantic without a history of the species spreading out of its native area (Pezold, 2022). It is a euryhaline species, ranging from brackish and nearly fresh water to hypersaline littoral lagoons, found in quiet waters of bays and estuaries, in grassy and muddy areas (Froese & Pauly, 2022). The possible limiting factor for the expansion of this euryhaline and eurythermal species is appropriate habitat of transitional waters and the possible presence of native competitors at those habitats. The Mediterranean records are quite remote from the native area, and most likely the shipping was the vector of species transfer (Table 1). Interestingly, the four non-Lessepsian gobiid migrants that are suspected to have arrived by ships are all also brackish or euryhaline and not strictly marine species (Table 1).

Compared to the total of 168 alien fishes in the Mediterranean Sea (with 37 species entering the Mediterranean via the Strait of Gibraltar, 14 species assumed to be introduced by aquaria hobbyists, aquaculture, by vessels or of doubtful origin, and 117 entering the Mediterranean Sea via the Suez Canal) (Kovačić *et al.*, 2021), the alien gobies lack both the Eastern Atlantic ingression and the aquarium/aquaculture components of origin found in other fishes (Table 1). Although Gobiidae are the most species-rich fish family among alien fishes in the Mediterranean Sea, they have not been very successful in expanding their distribution in the Mediterranean Sea. Other alien fishes in the Mediterranean Sea have been much more successful (Figure 2 in Turan, 2004). Lessepsian fishes have reached almost every corner of Mediterranean Sea, although with a sharp gradient of species richness decreasing with increased distance from the Levant (Turan, 2004). Similarly, alien fishes entering Mediterranean Sea via the Strait of Gibraltar also have arrived to the most remote coast of Levant, but again have been mostly concentrated closer to the entry point in the western Mediterranean Sea (Turan, 2004). Unfortunately, there is no published analysis of distributional success and ecological traits for all alien fishes in the Mediterranean Sea. The gobies, as small non-migrant epibenthic and cryptobenthic fishes able to spread only in the larval stage, probably have a disadvantage in expanding compared to highly mobile and migrant hyperbenthic, benthopelagic or pelagic fishes. Also it is possible that gobies are more stenothermic compared to mobile and migrant fishes, so the latter have a greater chance to encounter temperature variability in their native area and are, therefore, more adapted to temperature variability. Regarding the establishment success and colonization in Mediterranean, studies exist only for Lessepsian fishes (Belmaker *et al.*, 2013; Arndt & Shembri, 2015; Golani *et al.*, 2021). Most of the gobies are shallow shelf species which was shown to be a significant trait influencing successful spread of fishes through Suez Canal (Arndt & Shembri, 2015). Gobies are also benthic spawners and have adhesive eggs, which are also traits of successful Lessepsian colonizers according to Arndt & Shembri (2015). Golani *et al.* (2021) found no correlation between wide-range distribution and success in Lessepsian colonization of the Mediterranean by Red Sea fish species, contrary to an earlier study (Belmaker *et al.*, 2013). However, Golani *et al.* (2021) also noted that Red Sea species with a high abundance in their native habitat, which is similar to habitats prone to invasion in the Mediterranean, have become successful colonizers, and this can be attributed to many gobies.

It could be concluded, based on the known distributions of alien gobies in the Mediterranean, that gobies have limitations in spreading their distribution across the Mediterranean Sea. However, gobies share the species traits already found significant for the establishment success of Lessepsian fishes, and, considering their present Mediterranean species richness, gobiid Lessepsian migrants are successful in the colonization of the Levant and in the establishment of the populations in that particular Mediterranean area.

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