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THE FIRST RECORD OF BASTARD GRUNT *POMADASYS INCISUS* (BOWDICH, 1825) IN ALBANIAN WATERS (ADRIATIC SEA)

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ABSTRACT

The bastard grunt Pomadasys incisus *(Bowdich, 1825), an Atlantic species that entered the Mediterranean through the Strait of Gibraltar, exhibits a discontinuous distribution within the basin and remains rare in the Adriatic Sea. Here, we report the first record of* P. incisus *in Albanian waters and only the third confirmed occurrence in the Adriatic Sea. A single individual was captured on 9 October 2025 in the Bay of Vlorë at a depth of 48 m near aquaculture facilities. The specimen was identified based on diagnostic morphological features and measured 21 cm in total length and 125 g in weight. This record fills an important gap in the species' Mediterranean distribution, although the exact route of entry into the Adriatic remains unclear. The rarity of records suggests limited establishment; however, recent warming trends in the Adriatic may facilitate further expansion.*

Key words: *Pomadasys incisus*, bastard grunt, Albanian Coast, Adriatic Sea, Mediterranean Sea

PRIMO RITROVAMENTO DI *POMADASYS INCISUS* (BOWDICH, 1825) NELLE ACQUE ALBANESI (MARE ADRIATICO)

SINTESI

Il grugnitore bastardo Pomadasys incisus *(Bowdich, 1825), una specie atlantica entrata nel Mediterraneo attraverso lo Stretto di Gibilterra, presenta una distribuzione discontinua all'interno del bacino e rimane raro nell'Adriatico. Gli autori riportano il primo ritrovamento di* P. incisus *nelle acque albanesi e solo la terza presenza confermata nell'Adriatico. Un singolo individuo è stato catturato il 9 ottobre 2025 nella Baia di Valona a una profondità di 48 m, in prossimità di impianti di acquacoltura. L'esemplare è stato identificato sulla base di caratteristiche morfologiche diagnostiche e misurava 21 cm di lunghezza totale e 125 g di peso. La rarità delle segnalazioni suggerisce un insediamento limitato; tuttavia, i recenti trend di riscaldamento dell'Adriatico potrebbero favorire un'ulteriore espansione.*

Parole chiave: *Pomadasys incisus*, grugnitore bastardo, costa albanese, Adriatico, Mediterraneo

INTRODUCTION

The family Haemulidae comprises approximately 138 species distributed among 23 genera, inhabiting predominantly coastal waters of tropical and subtropical regions across the Atlantic, Indian, and Pacific Oceans. Members of this family are mainly marine, although some species occur in brackish environments and only a few inhabit freshwater systems (Fricke *et al.*, 2022; Van der Laan *et al.*, 2022). Within this family, the genus *Pomadasys* includes 29 species, of which three have been reported in the Mediterranean Sea: the striped piggy *Pomadasys stridens* (Forsskål, 1775), the bastard grunt *Pomadasys incisus* (Bowdich, 1825), and the silver grunt *Pomadasys argenteus* (Forsskål, 1775). Notably, all three species are considered non-indigenous to the Mediterranean basin.

Two of these species, *P. stridens* and *P. argenteus*, are Lessepsian migrants that entered the Mediterranean Sea from the Red Sea via the Suez Canal. *Pomadasys stridens*, native to the Indo-Pacific region, was first recorded in the Mediterranean around 1888 in Port Said and has since established populations throughout the eastern Mediterranean, where it is considered one of the most abundant Lessepsian fish, but also occasionally reaches the Italian coast (Golani *et al.*, 2002; Bilecenoglu *et al.*, 2009; Bodilis *et al.*, 2013; Tüzün & Gücü, 2023). More recently, *P. argenteus* was recorded for the first time in the Mediterranean in 2022 near Misrata, Libya, representing the second Red Sea haemulid species to colonize the basin (Fitori *et al*, 2023).

In contrast, *Pomadasys incisus* has an Atlantic origin. Originally described from Gambia, it is widely distributed along the eastern Atlantic coastline, ranging from South Africa to the Iberian Peninsula, including Macaronesian archipelagos such as the Canary Islands, Madeira, and Cape Verde. The species entered the Mediterranean Sea through the Strait of Gibraltar, probably during the mid-19th century, likely facilitated by favorable oceanographic conditions, including prevailing currents, increasing sea temperatures, and the availability of suitable habitats, particularly soft substrates in shallow waters (Francour *et al.*, 1994; Bodilis *et al.*, 2013; Doumpas *et al.*, 2020; Kovačić *et al.*, 2021). Following its introduction, *P. incisus* established populations in the northwestern Mediterranean, where it has shown increasing abundance in areas such as the Málaga coast, the Catalan Sea, and the Gulf of Lion (Bodilis *et al.*, 2013; Villegas-Hernández *et al.*, 2014).

Despite its first documented occurrence in the Mediterranean dating back to 1840, it is possible that *P. incisus* was present earlier but remained undetected until the mid-19th century. Since then, the species has been recorded across a wide range of Mediterranean localities, including the coasts of Algeria, Tunisia, Spain, France, Italy, Libya, Egypt, Israel, Lebanon, Syria, Turkey, Greece, Malta, Cyprus and Croatia (Bodilis *et al.*, 2013; Doumpas *et al.*, 2020; Çoker & Akyol, 2021). Nevertheless, its distribution remains discontinuous and locally variable, suggesting a complex colonization pattern.

The successful dispersal of *P. incisus* is likely linked to its broad ecological tolerance and life-history traits. This gonochoric species exhibits relatively fast growth and a moderate lifespan of up to seven years (Pajuelo *et al.*, 2003a,b). It inhabits both marine and brackish environments, typically at depths ranging from 10 to 100 m, and occupies a wide variety of habitats, including sandy and rocky substrates, seagrass meadows, as well as lagoons and estuarine systems. Its feeding ecology is similarly opportunistic, consisting mainly of benthic invertebrates. Reproductive patterns appear to vary geographically, *e.g.*, in warmer waters of the eastern Atlantic and the southern central Mediterranean, spawning takes place during a more prolonged season from June to November, while in the north-western Catalan Sea spawning season is shorter, occurring between July and September, and between August and October in the Gulf of Tunis, while, in contrast, all year round in the Canarian Archipelago (Pajuelo *et al.*, 2003a, 2003b: Fehri-Bedoui & Gharbi, 2008; Kapiris *et al.* 2008; Bodilis *et al.*, 2013; Villegas-Hernández *et al.*, 2014; Doumpas *et al.*, 2020).

Despite this ecological flexibility and relatively broad distribution, *P. incisus* remains poorly studied in the Mediterranean, and available data on its biology and population dynamics are limited (Kapiris *et al.*, 2008). Moreover, its occurrence is still sporadic, with only a few areas reporting consistent or high local abundances. This pattern suggests that both intrinsic biological factors and extrinsic environmental constraints may influence its establishment success and limit its wider expansion across the Mediterranean basin (Bodilis *et al.*, 2013).

In this context, documenting new occurrences is essential for improving our understanding of the species' distribution and ongoing biogeographical changes in the Mediterranean Sea. Here, we report the first record of *Pomadasys incisus* in Albanian waters, representing only the third confirmed occurrence of the species in the Adriatic Sea. This finding contributes to filling a significant gap in the known distribution of the species and provides further insight into its range expansion within the Mediterranean basin.

MATERIAL AND METHODS

On 9 October 2025, a single individual of *Pomadasys incisus* was accidentally captured by a trammel net in the Bay of Vlorë (southern Albania)

(40.444600 °N, 19.383164 °E) (Fig. 1). The specimen was caught at a depth of 48 m, approximately 500 m from the nearest coastline, in proximity to marine aquaculture cages. The seabed in this area is predominantly muddy, likely influenced by organic enrichment associated with fish farming activities. After capture, the specimen was brought ashore, then photographed and measured (length to the nearest millimeter and weight in grams) by one of the authors (S. Durmishaj). Since the specimen was part of a commercial catch, it was returned to the fishermen and later sold at the Fishing Center Oriku in Radhimë, a coastal village near the city of Vlorë.

Fig. 1: The map of the area with the indicated location (*) of the record of *Pomadasys incisus***.**
Sl. 1: Zemljevid obravnavanega območja z označeno lokaliteto ulova (*) vrste *Pomadasys incisus***.**

RESULTS AND DISCUSSION

The specimen was identified as *Pomadasys incisus* based on its diagnostic morphological features, including a relatively large head with a depth comparable to that of the body, a small and slightly oblique mouth, greyish coloration on the dorsum, and silvery-white coloration on the flanks and ventral side. Additional distinguishing characteristics included a dark spot on the posterior margin of the operculum and orange to yellowish fins (Fig. 2). These traits are consistent with previous descriptions of the species (Kapiris *et al*. 2008; Bodilis *et al*., 2013; Akyol & Ünal, 2016; Doumpas *et al*., 2020). Hence, the individual measured 21.0 cm in total length (TL) and weighed 125 g.

This record represents the first confirmed occurrence of *P. incisus* in Albanian waters and only the third documented sighting of the species in the Adriatic Sea. The first Adriatic record dates back to 15 August 2015, when a single individual was captured off the Pelješac Peninsula (Croatia) in the southern Adriatic (Karachle *et al*., 2016). The second known record was recently reported from the western side of the Adriatic Sea, when on 5 July 2025 a specimen was caught by a recreational fisher using rod and line in coastal waters at a depth of 25 m off Ancona harbour (Toma *et al*., 2025). No additional records have been reported in the Adriatic basin until the present study, suggesting either a very low detection probability or a sporadic occurrence pattern in this region.

The present finding is consistent with previously proposed dispersal pathways of *P. incisus* within the Mediterranean Sea (Bodilis *et al*., 2013). After entering through the Strait of Gibraltar, the species is thought to expand via two main routes: (1) an eastward pathway along the North African coastline, from Algeria to Tunisia and further into the Levantine basin, and (2) a northward pathway along the northern Mediterranean coasts, initially following Spain and France and subsequently extending toward other northern regions.

However, the occurrence of *P. incisus* in the Adriatic Sea raises questions regarding the exact dispersal route taken. Given the semi-enclosed nature of the Adriatic basin and its connection to the Mediterranean through the relatively narrow Strait of Otranto, individuals may have entered from the Ionian Sea, potentially originating from populations established along the North African coast (*e.g.*, Gulf of Tunis). Alternatively, a west-to-east dispersal route via the Tyrrhenian Sea cannot be excluded.

It is also important to consider the environmental constraints of the Adriatic Sea, which is generally recognized as one of the coldest sub-basins of the Mediterranean. Such conditions may have historically

Fig. 2: The left (A) and right (B) sides of the caught** Pomadasys incisus**.
Sl. 2: Leva (A) in desna stran (B) ujetega primerka vrste** Pomadasys incisus**.

limited the establishment and persistence of thermophilic species such as *P. incisus*. Nevertheless, recent oceanographic trends indicate a significant increase in sea temperature and salinity in the Adriatic over the past decade (Terzić *et al.*, 2025). These changes are likely facilitating the northward expansion of warm-affinity species, as increasingly documented across the Mediterranean basin.

In this context, the present record may reflect an ongoing shift in species distribution driven by climate-related changes. The sporadic but recurrent appearance of P. *incisus* in the Adriatic could represent early stages of colonization, although further records are needed to determine whether a stable population will establish.

Finally, such occurrences highlight the importance of reporting single records, as they can serve as early indicators of ecological change. The detection of non-indigenous or range-expanding thermophilic species may provide valuable insights into shifting environmental conditions and habitat suitability, often preceding detectable trends in long-term oceanographic datasets.

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PRVI ZAPIS O POJAVLJANJU NEPRAVE PRAŠIČEVKE *POMADASYS INCISUS* (BOWDICH, 1825) V ALBANSKIH VODAH (JADRANSKO MORJE)

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POVZETEK

Neprava prašičevka, Pomadasys incisus *(Bowdich, 1825), atlantska vrsta, ki je v Sredozemsko morje vstopila skozi Gibraltarsko ožino, kaže prekinjeno razširjenost znotraj bazena in ostaja redka v Jadranskem morju. Avtorji poročamo o prvi najdbi vrste* P. incisus *v albanskih vodah in šele o tretjem potrjenem pojavljanju v Jadranskem morju. Primerek te vrste je bil ulovljen 9. oktobra 2025 v Vlorovskem zalivu na globini 48 m v bližini marikulturnih objektov. Primerek smo določili na podlagi diagnostičnih morfoloških značilnosti ter je meril 21 cm v celotno dolžino in tehtal 125 g. Ta zapis o pojavljanju zapolnjuje pomembno vrzel v sredozemski razširjenosti te vrste, čeprav natančen način njenega vstopa v Jadransko morje ostaja nejasen. Redkost najdb kaže na omejeno ustalitev; vendar pa bi nedavni trendi segrevanja Jadranskega morja lahko olajšali nadaljnjo razširjanje.*

Ključne besede: *Pomadasys incisus***,** neprava prašičevka, albanska obala, Jadransko morje, Sredozemsko morje

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ADDITIONAL RECORDS OF THE BASTARD GRUNT, *POMADASYS INCISUS* (BOWDICH, 1825), FROM THE EASTERN ADRIATIC SEA

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ABSTRACT

The bastard grunt, Pomadasys incisus *(Bowdich, 1825), is a thermophilic coastal species that has historically been rare and only sporadically recorded in the northernmost Mediterranean sub-basins. Following the first confirmed Adriatic record in 2016, further observations have remained limited. The present study documents 11 individuals recorded between October 2023 and November 2025 from five localities in the eastern Adriatic. Records were obtained through validated citizen science contributions and were supported by photographic evidence. Most occurrences were concentrated between summer and autumn. This seasonal pattern, together with ongoing sea warming trends in the Adriatic, is consistent with the broader process of northward spreading of Mediterranean species.*

Key words: Haemulidae, northward spreading, citizen science, range expansion

ULTERIORI SEGNALAZIONI DEL GRUGNITORE BASTARDO *POMADASYS INCISUS* (BOWDICH, 1825) NELL'ADRIATICO ORIENTALE

SINTESI

Il grugnitore bastardo, Pomadasys incisus *(Bowdich, 1825), è una specie costiera termofila che storicamente è stata rara e segnalata solo sporadicamente nei sottobacini più settentrionali del Mediterraneo. Dopo la prima segnalazione confermata nell'Adriatico nel 2016, le successive osservazioni sono rimaste limitate. Il presente studio documenta 11 individui registrati tra ottobre 2023 e novembre 2025 in cinque località dell'Adriatico orientale. Le segnalazioni sono state ottenute tramite contributi validati di scienza partecipativa e supportate da prove fotografiche. La maggior parte delle osservazioni si è concentrata tra l'estate e l'autunno. Questo andamento stagionale, insieme ai continui trend di riscaldamento del mare Adriatico, è coerente con il più ampio processo di espansione verso nord delle specie mediterranee.*

Parole chiave: Haemulidae, espansione verso nord, scienza partecipativa, espansione dell'areale

INTRODUCTION

The bastard grunt, *Pomadasys incisus* (Bowdich, 1825), is a coastal thermophilic demersal species inhabiting marine and occasionally brackish environments, and typically occurring at depths between 10 and 100 m. It is most frequently associated with sandy or mixed substrates, but has also been recorded on rocky bottoms and in seagrass meadows (Kapiris *et al.*, 2008; Bodilis *et al.*, 2013). The genus *Pomadasys* Lacepède, 1802 (Haemulidae) is currently represented in the Mediterranean Sea by two species: *P. incisus* and *P. stridens* (Forsskål, 1775) (Froese & Pauly, 2025).

P. incisus is known to form relatively dense coastal aggregations and constitutes a characteristic component of shallow demersal fish assemblages (Pajuelo *et al.*, 2003a). It is gonochoric and exhibits a relatively rapid growth rate and a moderately short life span, with a maximum reported age generally reaching 7–8 years, depending on the study area (Pajuelo *et al.*, 2003b; Chater *et al.*, 2015).

The species was first documented in the Mediterranean Sea between 1840 and 1842, during surveys conducted along the Algerian coast (Guichenot, 1850, as reported in Bodilis *et al.*, 2013). This record, interpreted as evidence of natural migration from the eastern Atlantic through the Strait of Gibraltar, was followed by subsequent observations along the southern Mediterranean coastline and later in northern sectors of the basin, suggesting a progressive expansion within the Mediterranean (Bodilis *et al.*, 2013). In contrast, Doumpas *et al.* (2020) proposed that the species may have been historically present in certain areas of the Mediterranean but was overlooked or misidentified, implying that its apparent expansion could partly reflect increased sampling effort and improved taxonomic resolution rather than a recent biogeographical shift.

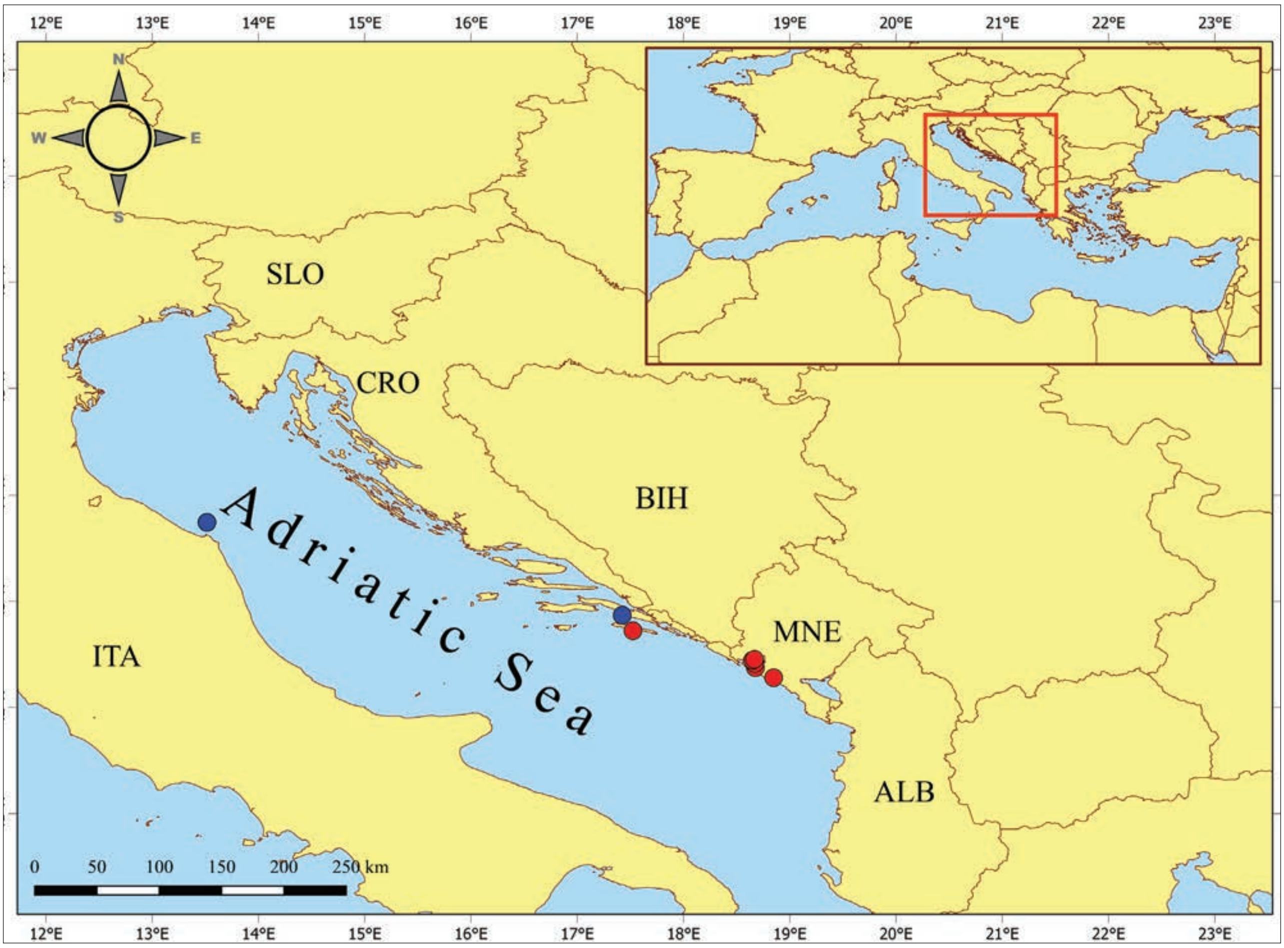

Fig. 1: Distribution of the bastard grunt (*P. incisus*) in the Adriatic Sea, including previ-ous records (blue dots) and records from this study (red dots).

Sl. 1. Razširjenost neprave prašičevke (*P. incisus*) v Jadranskem morju, vključno s prejšnjimi zapisi o pojavljanju (modre pike) in najdbami iz te študije (rdeče pike).

P. incisus has low commercial value and is rarely targeted by fisheries. In the Canary Islands, it constitutes one of the most abundant coastal demersal species within artisanal multispecies fisheries, although it is largely discarded due to limited market demand (Pajuelo, 1997; Pajuelo *et al.*, 2003a). In Mediterranean waters, the species is regularly recorded in landings and fish markets; however, given its marginal economic importance, total catches remain poorly quantified (Chater *et al.*, 2015) and the attention the species has received from a fisheries management perspective is comparatively limited (Kapiris *et al.*, 2008).

Although *P. incisus* has been present in the Mediterranean Sea for over a century, its occurrence in the northernmost sectors of the basin is relatively recent and remains sporadic. The first confirmed record in the Adriatic Sea originated from the shallow coastal waters of the Pelješac Peninsula in southern Croatia (Karachle *et al.*, 2016), and was followed nearly a decade later by one from the Italian side of the Adriatic (Toma *et al.*, 2025).

The primary objective of the present study was to provide additional verified records of *P. incisus* from the Adriatic Sea and thereby contribute to a more precise understanding of its current distribution and occurrence dynamics within the basin.

MATERIAL AND METHODS

Records of *P. incisus* from the Adriatic Sea were collected opportunistically between 2023 and 2025 through collaboration with professional and recreational fishers. Contributors contacted the authors directly by phone or via social media platforms, and follow-up communication was conducted to verify and supplement the information provided.

In 2025, following the first confirmed findings, a public announcement was published in the widely followed Facebook group "Živi svijet Jadranskog mora" ("The Living World of the Adriatic Sea", active in Croatia and Montenegro and managed by some of the authors of this paper. The announcement, which was subsequently disseminated by national and regional media news portals, included a call for information regarding further observations or captures of *P. incisus* to stimulate additional data collection. Records including both visual observations and captures reported through citizen science channels but lacking verifiable photographic evidence, were excluded from the present study. For each confirmed record, the following data were compiled: date of capture or observation, locality, number of individuals, and fishing gear used.

Species identification was based primarily on photographic material provided by contributors. Diagnostic morphological characters were assessed against published taxonomic descriptions for Mediterranean individuals of *P. incisus*. Identification followed the morphological criteria for the species provided by Bodilis *et al.* (2013): dorsum brownish, ventral side silvery, distinct dark blotch on upper corner of operculum; head relatively large; mouth small, slightly oblique; two distinct pores on tip of the chin. These features are consistent with earlier regional identification works for the Mediterranean ichthyofauna (*e.g.*, Ben-Tuvia & McKay, 1986).

RESULTS

During the study period, six confirmed occurrences of *P. incisus* were documented in the Adriatic Sea between October 2023 and November 2025, comprising a total of 11 individuals (Tab. 1). The recorded occurrences originated from five distinct localities, four in Montenegro (Bigova, Obala Đuraševića, Bijela, and Budva) and one in Croatia (Mljet Island). An overview of the distribution of all known records of *P. incisus* in the Adriatic Sea is presented in Fig. 1. Temporally, the records were concentrated in autumn (October–December), with a single exception in early summer (June 2024). No records were documented during winter or spring. Total length was not independently estimated from photographic material, as the study focused primarily on temporal frequency and spatial occurrence. In Fig. 2, the final panel shows a single individual, whereas Table 1 indicates two individuals for that record; the second specimen was not adequately photographed and was therefore not included in the figure. Notably, these records also represent the first confirmed occurrences of *P. incisus* in Montenegrin waters.

Tab. 1: Additional confirmed records of the bastard grunt** (Pomadasys incisus) **from the eastern Adriatic Sea.
Tab. 1: Dodatne potrjene najdbe neprave prašičevke** (Pomadasys incisus) **iz vzhodnega Jadranskega morja.

Record number	Date	Number of individuals	Location	Coordinates
1	06.10.2023	1	Bigova (Montenegro)	42.359561° N, 18.691744° E
2	15.06.2024	1	Obala Đuraševića (Montenegro)	42.402984° N, 18.692258° E
3	04.12.2024	5	Bijela (Montenegro)	42.448171° N, 18.657222° E
4	28.09.2025	1	Mljet (Croatia)	42.756347 N, 17.402503° E
5	05.10.2025	1	Budva (Montenegro)	42.276986° N, 18.844875° E
6	13.11.2025	2	Bijela (Montenegro)	42.448171° N, 18.657222° E

DISCUSSION

The new records of *P. incisus* presented in this study are consistent with the ongoing northward spreading of Mediterranean species affecting the Mediterranean Sea, including the Adriatic sub-basin, as has been widely documented over recent decades (Bianchi & Morri, 2003; Azzurro *et al.*, 2011; Bianchi *et al.*, 2019).

Although *P. incisus* has been present in the Mediterranean since at least the mid-19th century, its expansion towards northern sectors has historically been slow and spatially discontinuous. Despite its broad distribution, its presence in the northernmost sub-basins has remained patchy (Bodilis *et al.*, 2013).

The Ionian Sea represents the principal transitional corridor between the central Mediterranean and the Adriatic Sea and may facilitate northward dispersal. Historical records from the Greek Ionian are limited to a single specimen reported from Lefkada (Kaspiris, 1970). In contrast, more recent confirmed records from the Italian Ionian indicate a continued presence and gradual consolidation of *P. incisus* within that basin (Bilecenoğlu *et al.*, 2013; Tiralongo *et al.*, 2019; Tiralongo *et al.*, 2020).

The first confirmed record of *P. incisus* in the Adriatic Sea dates to 2016, when a single specimen was captured off the Pelješac Peninsula (southern Croatia) (Karachle *et al.*, 2016). No additional confirmed records were reported for several years thereafter. This apparent absence may have reflected either a true absence of the species from the area during that period or its occurrence at such low densities as to result in a limited detection probability.

The findings presented herein indicate a more recurrent presence in the southern Adriatic, suggesting an altered regional occurrence pattern. The recent record off Ancona, Italy (Toma *et al.*, 2025), further supports the interpretation of a northward extension within the Adriatic basin.

The northward expansion of this species in the Aegean Sea has already been documented. Fishermen in Gökova Bay (SE Aegean Sea) report that the populations have increased in recent years (Çoker & Akyol, 2021). In Cyprus, where *P. incisus* was formally documented only in 2020, it has been suggested that the species was likely present earlier but remained undetected due to local rarity (Doumpas *et al.*, 2020). This interpretation was supported by previous studies indicating that high abundances of *P. incisus* are typically reached only in subtropical habitats and warmer environmental conditions (Pajuelo *et al.*, 2003a; Pajuelo *et al.*, 2003b; Fehri-Bedoui & Gharbi, 2008), which are not uniformly encountered across the eastern Mediterranean.

Available Ionian and Adriatic records predominantly correspond to summer and autumn months (*e.g.*, Tiralongo *et al.*, 2020; Toma *et al.*, 2025). This seasonal pattern aligns with the broader framework described by Ben-Tuvia & McKay (1986) and discussed by Bodilis *et al.* (2013), whereby *P. incisus* occurs year-round in the warmest Mediterranean regions but appears in colder sectors mainly during thermally favourable periods. The concentration of Adriatic records between June and December therefore supports the interpretation of seasonal incursions into the northern basin.

Given the pronounced seasonal cooling and thus comparatively lower winter sea surface temperatures in the Adriatic, the hypothesis of a long-standing but overlooked resident population appears less plausible. Moreover, documented sea warming trends in the Adriatic (Grbec *et al.*, 2018; Terzić *et al.*, 2025) temporally coincide with the increasing number of records reported herein. This concordance is consistent with the broader process of northward spreading of thermophilic Mediterranean species into temperate sectors under ongoing climate warming.

Although the growing number of records suggests a wider regional presence, the available data remain insufficient to infer population size, structure, or long-term stability. The scarcity of verified *in situ* underwater observations further limits the assessment of establishment status and true abundance in the Adriatic. At present, the evidence supports recurrent seasonal presence rather than confirmed year-round persistence. However, the dataset remains limited in spatial and temporal resolution. Clarifying population dynamics will require systematic and temporally standardised monitoring.

The continued integration of structured, rigorously validated citizen science contributions, alongside improved communication among professional and recreational stakeholders, may enhance detection reliability while minimising misidentification. Such coordinated efforts will be essential for accurately assessing the temporal and spatial dynamics of *P. incisus* in the Adriatic Sea, where current evidence suggests that observed records may represent either episodic incursions or the early stages of regional persistence.

CONCLUSIONS

The newly documented records confirm the repeated occurrence of *P. incisus* in the eastern Adriatic Sea. The temporal pattern of observations, concentrated mainly between summer and late autumn,

Fig. 2: Specimens of** P. incisus **recorded in the Adriatic Sea during the study period, arranged in chronological order from left to right and top to bottom. (Photos from top left to bottom right: S. Lazarević, M. Malović, S. Andričić, M. Orlandini, B. Vujović, A. Vodovar).
Sl. 2: Primerki vrste** P. incisus, **zabeleženi v Jadranskem morju v obdobju študije, razvrščeni v kronološkem vrstnem redu od leve proti desni in od zgoraj navzdol. (Fotografije od zgoraj levo do spodaj desno: S. Lazarević, M. Malović, S. Andričić, M. Orlandini, B. Vujović, A. Vodovar).

suggests seasonal incursions rather than confirmed year-round persistence. These findings are consistent with the broader northward spreading of Mediterranean thermophilic species associated with ongoing sea warming. Continued monitoring and integration of validated citizen science observations will be essential in determining whether the species has established a stable population in the Adriatic Sea.

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DODATNE NAJDBE NEPRAVE PRAŠIČEVKE, *POMADASYS INCISUS* (BOWDICH, 1825), IZ VZHODNEGA JADRANSKEGA MORJA

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POVZETEK

Neprava prašičevka, Pomadasys incisus *(Bowdich, 1825), je termofilna obalna vrsta, ki je bila zgodovinsko gledano redka in le sporadično zabeležena v najsevernejših podbazenih Sredozemskega morja. Po prvem zapisu o pojavljanju v Jadranskem morju leta 2016 so kasnejši podatki o najdbi te vrste še vedno redki. Pričujoča raziskava dokumentira 11 osebkov, zabeleženih med oktobrom 2023 in novembrom 2025 na petih lokalitetah v vzhodnem Jadranu. Podatki o najdbah so bili pridobljeni s prispevkom občanske znanosti in podprti s fotografskim gradivom. Večina podatkov o pojavljanju je bila zbrana med poletjem in jesenjo. Ta sezonski vzorec je skupaj s trendi ogrevanja Jadranskega morja skladen s širšim procesom tropikalizacije Sredozemskega morja.*

Ključne besede: Haemulidae, tropikalizacija, občanska znanost, širjenje areala

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SIGNIFICANT RANGE EXPANSION OF *SEPIOTEUTHIS LESSONIANA* (CEPHALOPODA: LOLIGINIDAE) IN THE AEGEAN SEA BASED ON SCUBA AND PHOTOGRAPHIC OBSERVATIONS

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ABSTRACT

The bigfin reef squid, Sepioteuthis lessoniana*, is by far the most widespread Lessepsian cephalopod in the Mediterranean Sea and has considerably expanded its range since it was first recorded almost two decades ago. In Türkiye, the species' occurrence was hitherto restricted to the northern Levantine shores, with reports from Iskenderun, Antalya, and Fethiye Bays. This study reports the presence of* S. lessoniana *from the Aegean Sea coast of Türkiye for the first time, suggesting a significant northward range of expansion. The observed individuals displayed spawning behavior, and several egg masses were deposited within inshore crevices, indicating the potential presence of a successfully breeding population in the region.*

Key words: Bigfin reef squid, Lessepsian migrant, range expansion, invasive species, first record

ESPANSIONE SIGNIFICATIVA DELL'AREALE DI *SEPIOTEUTHIS LESSONIANA* (CEFALOPODA: LOLIGINIDAE) NEL MAR EGEO BASATA SU OSSERVAZIONI SUBACQUEE E FOTOGRAFICHE

SINTESI

Il calamaro di Lesson, Sepioteuthis lessoniana*, è di gran lunga il cefalopode lessepsiano più diffuso nel Mediterraneo e ha ampliato considerevolmente il proprio areale da quando è stato segnalato per la prima volta quasi due decenni fa. In Turchia, la presenza della specie era finora limitata alle coste settentrionali del Levante, con segnalazioni dalle baie di Iskenderun, Antalya e Fethiye. Questo studio riporta per la prima volta la presenza di* S. lessoniana *lungo la costa egea della Turchia, suggerendo una significativa espansione dell'areale verso nord. Gli individui osservati mostravano comportamenti riproduttivi e diverse masse di uova sono state deposte all'interno di fessure costiere, indicando la possibile presenza di una popolazione in riproduzione con successo nella regione.*

Parole chiave: calamaro di Lesson, migrante lessepsiano, espansione dell'areale, specie invasiva, prima segnalazione

INTRODUCTION

The occurrence and establishment success of non-indigenous cephalopods in the Mediterranean Sea have long been neglected and have only become a focus of scientific interest over the past two decades (Bello *et al*., 2020). According to the most comprehensive accounts, five Lessepsian species originating from the Red Sea and Indo-Pacific are currently recognized, namely *Sepia dollfusi*, *Sepioteuthis lessoniana*, *Uroteuthis arabica*, *Octopus cyanea*, and *Amphioctopus aegina* (Marrone et *al*., 2025), while two additional species (*Acanthosepion pharaonis* and *Tremoctopus gracilis*) are either regarded as questionable or requiring further research to clarify their pathways of introduction (Bello *et al*., 2020).

Among all alien cephalopod species in the Mediterranean Sea basin, the status of the bigfin reef squid, *S. lessoniana* R.P. Lesson, 1831, is of special concern owing to its invasive potential. This neritic loliginid species is native to the Indo-Pacific region, with a broad distribution from the eastern coast of Africa and the Red Sea in the west to the Hawaiian Islands in the east, and from Japan in the north to Australia and New Zealand in the south (Jereb & Roper, 2010). The species was first recorded in the Mediterranean Sea in 2002, when a single individual was captured in Iskenderun Bay, Türkiye (Salman, 2002). Within just seven years, its range expanded to Rhodes Island, Greece, most likely along the Asiatic shores of the Mediterranean, aided by the prevailing currents (Lefkaditou *et al*., 2009). Rapidly spreading westward to the central Mediterranean, *S. lessoniana* has reached as far as Tunisia in the south and the Adriatic Sea in the north, becoming a commercial catch in several localities (Bello *et al*., 2020; Marrone *et al*., 2025).

Published information on *S. lessoniana* in Türkiye is quite scarce. Following its first record by Salman (2002), small schools of up to 15 individuals were observed in Fethiye Bay during a governmental biodiversity project (anonymous, 2009), with subsequent records reported from Kaş (Draman, 2012) and Antalya Bay (Salman *et al*., 2023). The species was included in the list of invasive marine species of Türkiye (105 species in total) by Çınar *et al*. (2021). In this paper, we report a new occurrence of *S. lessoniana* from Kuşadası Bay (Türkiye), based on photographic data obtained through SCUBA diving observations. This recent finding confirms a significant range expansion of the species in the Aegean Sea, and careful monitoring is warranted due to its potential intrusion further northward.

MATERIAL AND METHODS

On 17 August 2025, three individuals of *S. lessoniana* were observed at a depth of 5 m during a recreational SCUBA dive carried out at Kuşadası Bay (37°52′39″N, 27°15′55″E) on the central Aegean Sea coast of Türkiye. The diving site is a shallow, small cove with a sandy and rocky substrate up to 3 m deep, and dense seagrass meadows (*Posidonia oceanica*) at greater depths. Since the squids approached the divers very closely, it was possible to estimate their approximate mantle lengths, which ranged from 20 cm for two individuals to 30 cm for the third. Additional observations of three more bigfin reef squid individuals (of the same size classes) were made at the same cove on 20 September 2025, just slightly farther offshore and at a greater deepth (7 m) than the previous observation site. Wide-angle underwater photographs were taken with a Panasonic DMC-TZ10 compact digital camera, while close-up images were captured using an Olympus OM-1 mirrorless dSLR camera equipped with a 90 mm lens. Species identification was based on photographic records following Jereb & Roper (2010), and nomenclature follows the WoRMS Editorial Board (2025).

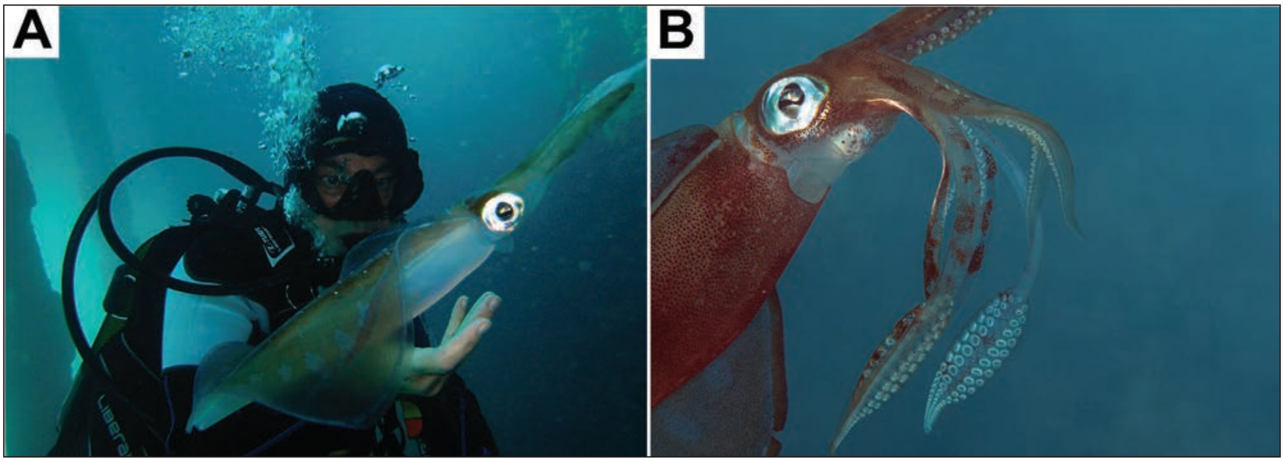

Fig. 1: Underwater photographs of** Sepioteuthis lessoniana **from Kuşadası Bay, Aegean Sea, Türkiye. A) Lateral view (photograph by C. Gedikoğlu), B) Close-up showing tentacular clubs (photograph by R. Kirman).
Sl. 1: Podvodne fotografije vrste** Sepioteuthis lessoniana **iz zaliva Kuşadası (Egejsko morje, Turčija). A) stranski pogled (foto: C. Gedikoğlu), B) bližnji posnetek, ki prikazuje tentakularne kijaste izrastke (foto: R. Kirman).

RESULTS AND DISCUSSION

A close examination of underwater photographs confirmed the species to be *S. lessoniana*, which is characterized by a broadly elliptical cuttlefish-like morphology with thick, muscular, oval fins extending over 85% of the mantle length to the posterior end, forming a continuous edge without separate lobes (Fig. 1A), suckers arranged in four series on proximal tentacular clubs, enlarged median manal suckers, and large eyes (Fig. 1B); all consistent with the descriptions of Jereb & Roper (2010). The proportion of fin length relative to mantle length is the key diagnostic feature that distinguishes the bigfin reef squid from the other Mediterranean confamilial members and facilitates species identification from underwater photographs.

Documenting the first introductions of invasive species in a country or region is crucial for early detection and rapid response, although this is often hindered by observer lag (delay between the species' actual arrival and its first published record) (González-Moreno *et al.*, 2025). Our study site, Kuşadası Bay, has been regularly and frequently monitored through scuba diving and underwater photography by the author over the past decade, providing the research team with the opportunity to rapidly detect any newly arrived species to the region. The initial bigfin reef squid observation in August 2025 thus most likely reflects a recent development that warrants close monitoring. Since the location of this new record is over 300 nautical miles north of the site where the species was previously observed (Fethiye Bay), we speculate that the bigfin reef squid may already be present in other areas of the southern Aegean shores (*i.e.*, Gökova Bay), where it is currently unrecorded. The spreading pattern of *S. lessoniana* along the Turkish coastline (Fig. 2) is consistent with that of several other Lessepsian species that first established populations on the southern Anatolian shelf and then gradually expanded their distribution ranges toward the Aegean Sea, following the prevailing counterclockwise currents of the Mediterranean Sea (Çinar *et al.*, 2021).

During our diving observations in Kuşadası Bay, bigfin reef squid were first encountered hovering in midwater, then two individuals approached a nearby crevice. Both were estimated to exceed 20 cm in mantle length, indicating sexual maturity according to the developmental stage descriptions of Segawa (1987). Based on the reproductive

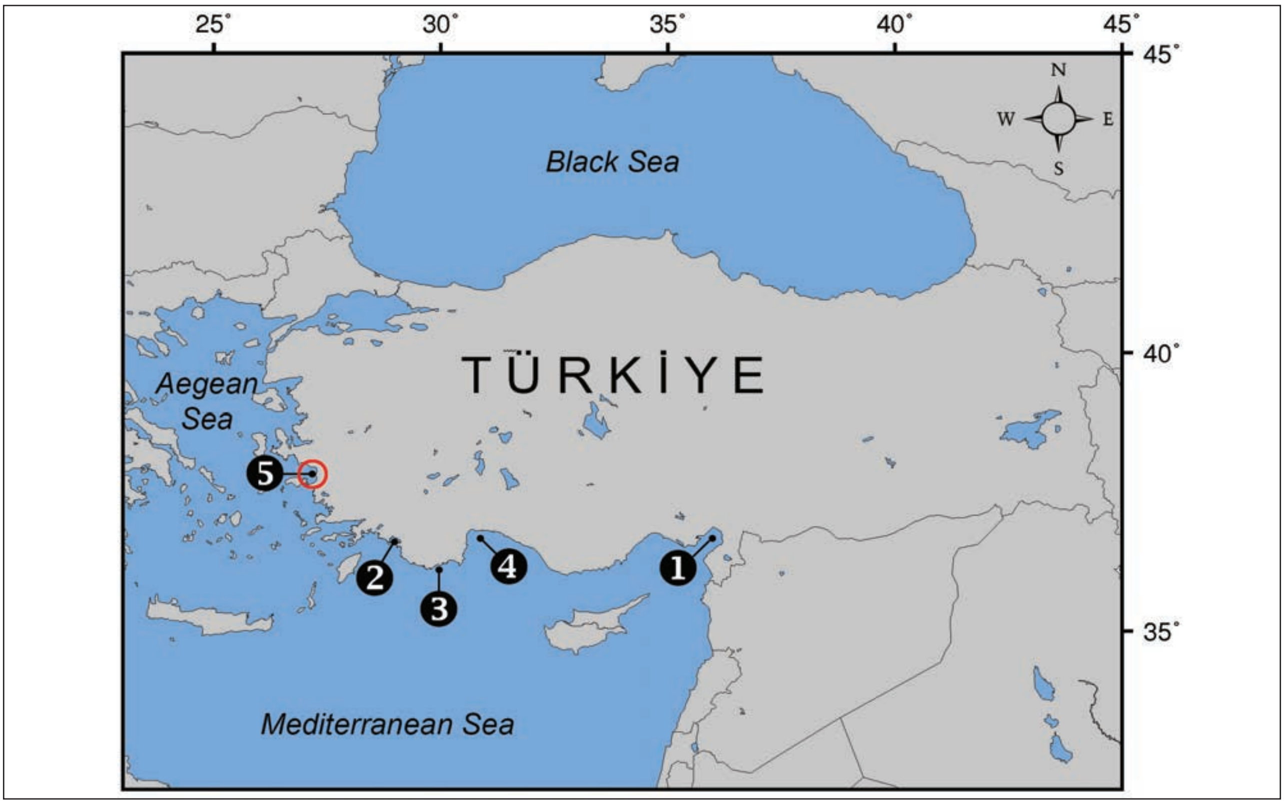

Fig. 2: Location of the** S. lessoniana **observation in the Aegean Sea (encircled in red). Previous occurrence records from Türkiye are indicated in chronological order: 1) Iskenderun Bay (Salman, 2002), 2) Fethiye Bay (anonymous, 2009), 3) Kaş (Draman, 2012), 4) Antalya Bay (Salman** et al.**, 2023), 5) Kuşadası Bay (present study).

Sl. 2: Lokacija opazovanja vrste** S. lessoniana **v Egejskem morju (obkroženo z rdečo). Predhodni zapisi o pojavljanju v Turčiji so navedeni v kronološkem zaporedju: 1) zaliv Iskenderun (Salman, 2002), 2) zaliv Fethiye (anonimno, 2009), 3) Kaş (Draman, 2012), 4) zaliv Antalya (Salman in sod., 2023), 5) zaliv Kuşadası (pričujoča raziskava).

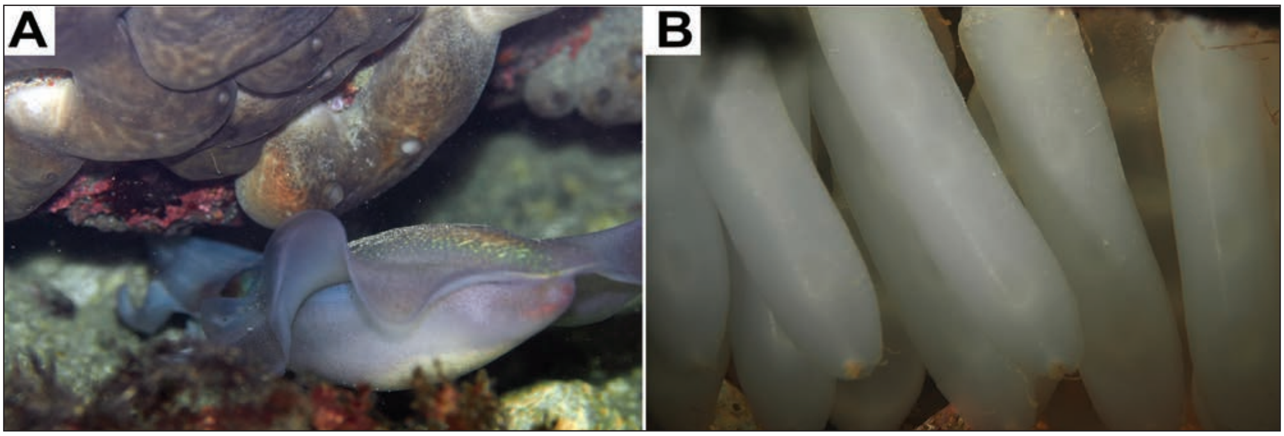

Fig. 3: Breeding behavior of* S. lessoniana *observed at the study site. A) Female entering the crevice to lay eggs, B) Egg masses attached to the crevice roof (photographs by R. Kirman).
Sl. 3: Razmnoževalno vedenje vrste* S. lessoniana*, opazovano na lokaciji raziskave. A) Samica, ki vstopa v razpoko, da bi odložila jajčeca, B) Jajčne mase, pritrjene na strop razpoke (foto: R. Kirman).

body patterns described for the species (Lin *et al*., 2017), the smaller individual (ca. 20 cm ML) exhibiting spots on the dorsal mantle, was identified as a female, whereas the larger one (30 cm ML), displaying lines on the dorsal mantle, was identified as a male. As the female entered the crevice and stayed inside for a short period (Fig. 3A), the male remained stationary outside. Similar activity – later confirmed as spawning behavior – has been reported for the southern reef squid (*S. australis*) in the Indo-Pacific region (Larcombe & Russell, 1971). After both individuals left the area, we approached the crevice and observed the egg masses. There were multiple batches of capsules attached to the crevice roof (Fig. 3B). Photographs from our study site indicate the presence of 2 to 6 egg masses, with each capsule – according to the literature (Jereb & Roper, 2010) – potentially containing up to 13 eggs. Field observations from the Pacific further indicate that adult *S. lessoniana* migrate from offshore to shallow inshore areas for spawning (Segawa, 1987), and that reproduction occurs almost year-round (Jereb & Roper, 2010; Chen *et al*., 2015), with seasonal peaks ranging from two (spring and autumn; Ching *et al*., 2017) to three (winter, spring, and summer; Kimoto *et al*., 2023), depending on the ecosystem.

The bigfin reef squid is distributed throughout the central and eastern Mediterranean Sea; however, its potential threat to local food webs and biodiversity is not currently a focus of ongoing research efforts. Lefkaditou *et al*. (2009) highlighted potential competition with native species, such as *Loligo vulgaris*, as both generally occupy similar habitats (*i.e.*, sandy bottoms and seagrass beds) and are abundant at depths of up to 100 m (Jereb & Roper, 2010). Such interspecies interactions might lead to changes in fisheries practices due to shifts in catch composition. Owing to its high commercial value in artisanal and nearshore fisheries across the Indo-Pacific, the bigfin reef squid is one of the most extensively studied loliginid species within its native range; however, its life-history traits in newly colonized environments remain under-researched and quantifying the actual ecological and socioeconomic consequences will require targeted studies. It is important to note that Mediterranean records of *S. lessoniana* should be critically validated (Bello *et al*., 2020), as substantial morphological and genetic evidence suggests extremely high levels of cryptic diversity within the species complex (Cheng *et al*., 2015).

Several biological traits of *S. lessoniana* may increase its potential to exhibit invasive characteristics and colonize new areas. These include rapid growth, a relatively short lifespan (up to 7 months) with first maturity at 120 days (Kavitha *et al*., 2024), year-round reproduction (Jereb & Roper, 2010), flexible spawning substrate selection (Kimoto *et al*., 2023), and high tolerance to thermal fluctuations (Chiang *et al*., 2024). Together, these traits contribute to quick rapid population responses to favorable environmental conditions, facilitating reproduction and range expansion. Our recent observation of occurrence and breeding activity of *S. lessoniana* along the central Aegean Sea coast provides strong evidence of an established population in the region, although it remains unclear whether it can withstand existing physical and ecological pressures. Since invasive species often exhibit complex interactions with members of recipient ecosystems, implementing appropriate environmental management decisions is a challenging task (Katsanevakis *et al*., 2014). Priority should therefore be given to assessing the magnitude of potential impacts, which requires in-depth research of the life histories and ecologies of native and Lessepsian loliginid species to evaluate possible competition.

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ZNATNO RAZŠIRJANJE AREALA VRSTE *SEPIOTEUTHIS LESSONIANA* (CEPHALOPODA: LOLIGINIDAE), V EGEJSKEM MORJU NA PODLAGI PODVODNIH OPAZOVANJ IN FOTOGRAFIRANJA

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POVZETEK

*Velikoplavuti grebenski ligenj (*Sepioteuthis lessoniana*) je daleč najbolj razširjen lesepski glavonožec v Sredozemskem morju in je od prve zabeležbe pred skoraj dvema desetletjema znatno razširil svoj areal. V Turčiji je bil doslej zabeležen le na severno obalo Levantskega morja, z zapisi o pojavljanju iz zalivov Iskenderun, Antalya in Fethiye. Ta raziskava prvič poroča o prisotnosti vrste* S. lessoniana *ob egejski obali Turčije, kar kaže na znatno širjenje njenega območja razširjenosti proti severu. Pri opazovanih osebkih sta avtorja zaznala razmnoževalno vedenje, v obalnih razpokah pa je bilo odloženih več jajčnih mas, kar kaže na morebitno prisotnost uspešno razmnožujoče se populacije v regiji.*

Ključne besede: velikoplavuti grebenski ligenj, lesepska selivka, širjenje areala, invazivna vrsta, prvi zapis o pojavljanju

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CONQUERING THE NORTH: NEW OCCURRENCE OF THE COMMON LIONFISH, *PTEROIS MILES* (BENNETT, 1828), IN THE ADRIATIC SEA

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ABSTRACT

The devil firefish, also known as the common lionfish, Pterois miles *(Bennett, 1828), was first recorded in the Mediterranean Sea in 1991, which it likely entered through the Suez Canal. Here, we present the northernmost record of the non-indigenous devil firefish in the Adriatic Sea since its first appearance in 2019. The specimen was observed by snorkelling at Sakarun Bay (Dugi Otok, Croatia) in June 2025 and was caught with a speargun. The immature specimen measured 149.0 mm in total length (106.8 mm standard length) and weighed 36.1 g.*

Key words: devil firefish, northernmost record, non-indigenous species, Sakarun Bay

CONQUISTANDO IL NORD: NUOVA SEGNALAZIONE DEL PESCE LEONE, *PTEROIS MILES* (BENNETT, 1828), NEL MAR ADRIATICO

SINTESI

Il pesce leone, noto anche come pesce scorpione, Pterois miles *(Bennett, 1828), è stato segnalato per la prima volta nel Mediterraneo nel 1991, dove probabilmente è entrato attraverso il Canale di Suez. Gli autori presentano il ritrovamento più settentrionale di questa specie non indigena nell'Adriatico, dalla sua prima comparsa nel 2019. L'esemplare è stato osservato durante attività di snorkeling nella baia di Sakarun (Dugi Otok, Croazia) nel giugno 2025 ed è stato catturato con un fucile subacqueo. L'esemplare immaturo misurava 149,0 mm di lunghezza totale (106,8 mm di lunghezza standard) e pesava 36,1 g.*

Parole chiave: pesce leone, ritrovamento più settentrionale, specie non indigena, baia di Sakarun

INTRODUCTION

The increasing occurrence of tropical and subtropical biota in the Mediterranean Sea is largely driven by climate change and various anthropogenic pressures (Bianchi & Morri, 2003). This process is manifested through the spreading of thermophilic native and non-indigenous species (NIS) across the progressively warming Mediterranean basin (Shaltout & Omstedt, 2014). In addition to overfishing, pollution and sea warming, invasive NIS are the greatest threat to biodiversity in the region (Costello *et al.*, 2010). A species is considered invasive when it causes harmful effects on ecosystem diversity and/or socio-economic values in the invaded area (Kuhlenkamp & Kind, 2017). One such species is the devil firefish, also known as the common lionfish, *Pterois miles* (Bennett, 1828). This fish species was first recorded in the Mediterranean Sea in 1991, which it likely entered through the Suez Canal, although introduction via ballast waters or aquarium trade has also been suggested (Golani & Sonin, 1992; Dimitriou *et al.*, 2019). *P. miles* is an opportunistic demersal mesopredator that feeds on a wide range of teleost fishes and crustaceans, some of which have economic importance (Savva *et al.*, 2020). Its native range spans the Indian Ocean, from South Africa to the Red Sea and eastwards to Sumatra (Schultz, 1986). Its introduction to the western Atlantic was confirmed in 2007, where it is present alongside its congener, the red lionfish *Pterois volitans* (Linnaeus, 1758) (Hamner *et al.*, 2007). The two species share the number of dorsal fin spines (13), anal fin spines (3) and pectoral fin rays (14), but usually differ in the number of dorsal and anal fin rays: *P. miles* has 10 and 6, while *P. volitans* has 11 and 7, respectively (Schultz, 1986). Due to its rapid spread and ecological impacts, the common lionfish has recently been recognized as invasive in the Mediterranean Sea (Kletou *et al.*, 2016). Moreover, further invasion has been predicted to occur along the eastern coast of the Adriatic Sea (Bakiu *et al.*, 2024), alongside a likely occupation of the northern Adriatic niches, which resemble the niches already occupied by the species within its native range (Poursanidis *et al.*, 2020).

P. miles was first recorded in the Adriatic Sea in 2019 (Di Martino & Stancanelli, 2021), after which a documented northwards progression along the eastern Adriatic coast is reflected in an increasing number of sightings in recent years (Crocetta *et al.*, 2021; Dragičević *et al.*, 2021; Fortič *et al.*, 2023; Bakiu *et al.*, 2024; Dulčić *et al.*, 2024; Dragičević & Ugarković, 2025). The northernmost record of the devil firefish in the available literature so far was near Mali Garmenjak Island in Telašćica Nature Park in August 2024 (Dragičević & Ugarković, 2025). Here, we provide a new northernmost record of *P. miles* in both the Adriatic Sea and the Mediterranean

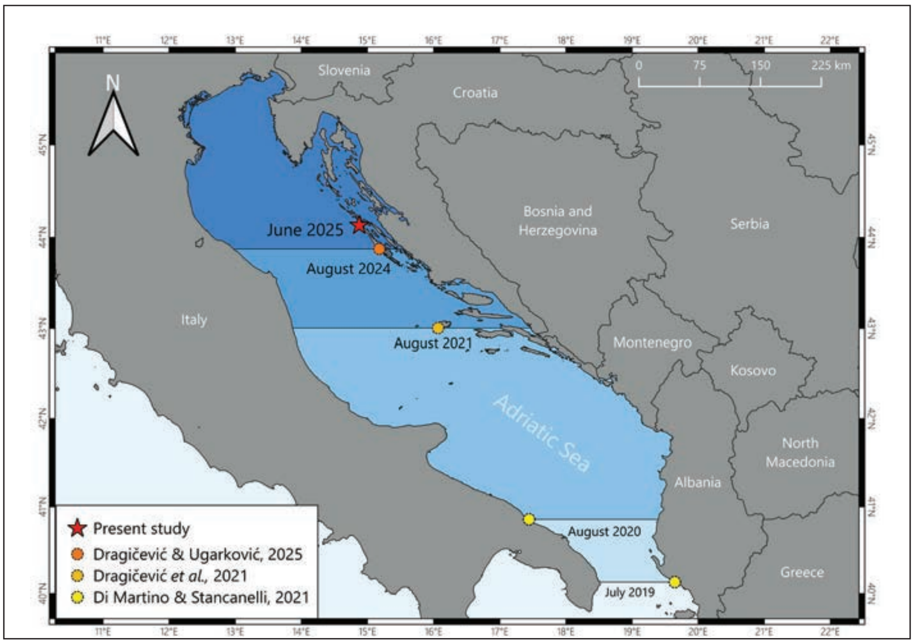

Fig. 1: *Pterois miles* **northwards range expansion in the Adriatic Sea, from July 2019 to June 2025.**

Sl. 1: ***Širjenje areala vrste*** *Pterois miles* ***proti severu v Jadranskem morju, od julija 2019 do junija 2025.***

Sea (Fig. 1). This represents the first record in the northern Adriatic region north of the Ancona-Zadar line, according to the traditional division of the Adriatic Sea proposed by Cushman-Roisin *et al.* (2001).

MATERIAL AND METHODS

Specimen collection and analysis

The specimen of *P. miles* was recorded on June 18, 2025, in the western periphery of the Sakarun Bay (44°07′53.8″N; 14°52′21″E) (Fig. 2). It was identified according to the meristic and morphometric features described in Schultz (1986). The individual was observed over rocky substrate at a depth of 1.9 m, and a sea temperature of 22 °C. At the time of observation, the fish was resting on a section of discarded fishing gear; however, it was neither entangled nor otherwise obstructed by it. The individual was positioned vertically, with the anterior oriented downward, and remained motionless while being observed and photographed. Following a brief observation of its behaviour, the specimen was collected using a speargun and subsequently transported in an ice box to the laboratory of the Faculty of Natural Sciences in Pula for further analysis.

The examination included measurements of body mass, meristic and morphometric characteristics, stomach content analysis to assess dietary habits, and sex determination. Morphometric measurements were adapted for this species (Fig. 3) following the guidelines presented in Lipej & Trkov (2024). All morphometric characters were measured using a digital calliper with a precision of 0.1 mm, while the specimen was weighed on a digital scale with a precision of 0.1 g.

Habitat description

Sakarun Bay is located on the outer coastline of the northwestern part of Dugi Otok Island, in the Zadar Archipelago of the eastern Adriatic Sea (Croatia). This area has been designated as a significant landscape since 1967 (MINGOR, 2022). Although Sakarun Bay lies within a protected area, it is subject to considerable anthropogenic pressure due to its popularity as a tourist destination. The bay is sheltered from NE, N, NW, and W winds, while being significantly exposed to S and SE winds. Exposure to SE wave action results in the seasonal accumulation of banquettes formed by the seagrass *Posidonia oceanica* along the approximately 300 m long beach. These banquettes play a crucial role in preventing coastal erosion of the sandy

Fig. 2: The specimen of *Pterois miles* **photographed and caught on June 18, 2025, in Sakarun bay. (Photo: Adrian Brajković)**
Sl. 2: Primerek vrste *Pterois miles***, fotografiran in ulovljen 18. junija 2025 v zalivu Sakarun. (Foto: Adrian Brajković)**

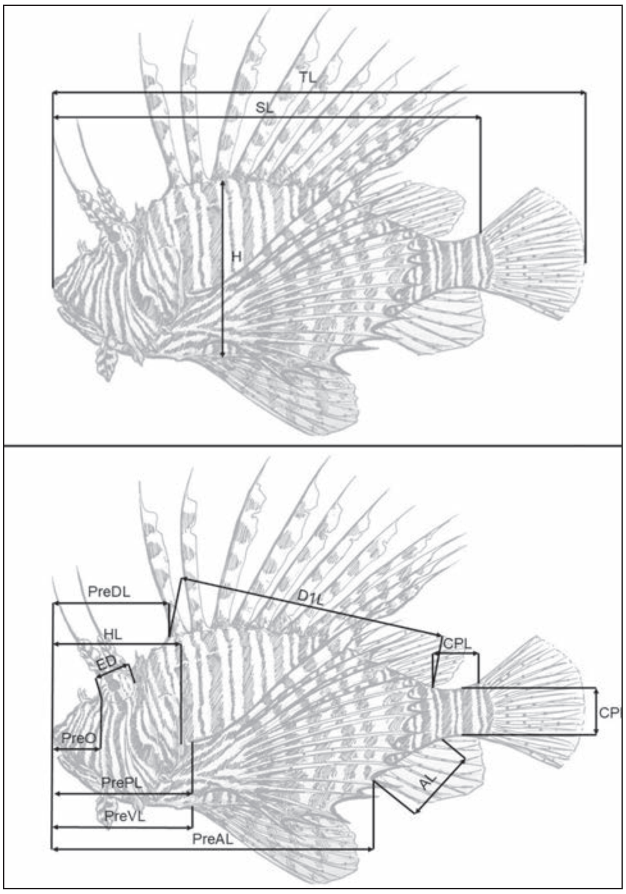

Fig. 3: The morphometric measures of** Pterois miles**, adapted from Lipej & Trkov (2024): TL – Total length, SL – Standard length, H – Body height, PreDL – Predorsal length, HL – Head length, ED – Eye diameter, PreO – Preorbital length, PrePL – Prepectoral length, PreVL – Preventral length, PreAL – Preanal length, D1L – Dorsal fin base length, AL – Anal fin base length, CPL – Caudal peduncle length, CPH – Caudal peduncle height.

Sl. 3: Morfometrične meritve vrste** Pterois miles**, prilagojeno po Lipej & Trkov (2024): TL – celotna dolžina, SL – standardna dolžina, H – višina telesa, PreDL – predhrbtna dolžina, HL – dolžina glave, ED – premer očesa, PreO – predorbitalna dolžina (dolžina gobca), PrePL – predprsna dolžina, PreVL – predtrebušna dolžina, PreAL – predpodrepna dolžina, D1L – dolžina osnove hrbtne plavuti, AL – dolžina osnove podrepne plavuti, CPL – dolžina repnega pedunkla, CPH – višina repnega pedunkla.

substrate, which led to the discontinuation of their removal during the tourist season as of 2020 (Pikelj *et al.*, 2022).

Sakarun Bay beach is classified as a large pocket beach characterized by mixed pebbly-sandy sediments and a gently sloping seabed that does not exceed a depth of approximately 20 m. The bay is enclosed by a coastal margin composed of biogenic carbonate rock, which forms the rocky substrate along the periphery of the bay, while the central seabed primarily consists of sandy deposits (Pikelj & Juračić, 2013; Pikelj *et al.*, 2022). The rocky substrate is an extension of the island's karstic terrain and supports an infralittoral algal biocenosis dominated by species such as *Dictyota* sp., *Padina pavonica*, *Laurencia obtusa* and *Halimeda tuna*. Additionally, this habitat forms structurally complex microhabitats associated with a pre-coralligenous biocenosis. Numerous crevices and cavities provide shelter for benthic fish species, including the dusky grouper *Epinephelus marginatus* (Lowe, 1834) and the cardinalfish *Apogon imberbis* (Linnaeus, 1758). Most of the seabed within Sakarun Bay is covered by extensive *P. oceanica* seagrass meadows, while shallow areas, particularly those shallower than 3 m, represent an exception to this general pattern.

RESULTS AND DISCUSSION

The examined specimen measured 149.0 mm TL (106.8 mm SL) and weighed 36.1 g (Tab. 1). The meristic traits were taken for dorsal (D) and anal (A) fins, which represent identifying features of *P. miles* (Schultz, 1986): D XIII+10; A III+6. The specimen had a moderately compressed body marked with a pattern of narrow light brown, narrow white and wide red alternating bars. A similar pattern covered the dorsal, pectoral and pelvic fins, while the soft rays of the anal, caudal and dorsal fins were transparent and adorned with black dots. There were multiple cirri (skin flaps) on the head: an antenna-like pair above the eyes, a pair above the nostrils and six of unequal size along each side of the upper jaw. The stomach contents could not be reliably identified through visual examination due to the highly digested state of the material at the time of analysis. The sex of the specimen could not be determined, possibly due to the fact that it had not yet reached sexual maturity. For example, a study from Cyprus has shown that the smallest males and females capable of reproducing had a TL of 154 mm and 158 mm, respectively (Savva *et al.*, 2020). More recent studies from the eastern Mediterranean have shown that the onset of sexual maturity occurs at even larger TL. Kondylatos *et al.* (2024) suggested a size of 219.2 mm and 229 mm for males and females respectively, while Yıldız *et al.* (2025) gave an estimate of 201 mm for female lionfish.

Pterois spp. are opportunistic predators capable of exploiting a wide range of teleost fishes and crustaceans associated with rocky habitats (Savva *et al.*, 2020; Bottacini *et al.*, 2024). Their presence in such environments may therefore increase predation pressure and competition within native fish assemblages, as previously documented in other invaded regions

(Albins & Hixon, 2013), and could potentially influence trophic dynamics in Adriatic coastal ecosystems. This finding confirms the ongoing northward expansion of *P. miles* along the eastern Adriatic coast. Until recently, the northernmost documented occurrence of the species in the Adriatic Sea was reported near Mali Garmenjak Island in Telašćica Nature Park (Dragičević & Ugarković, 2025). The finding of a specimen at Sakarun Bay therefore represents a further extension of the known distribution range and the first confirmed occurrence of *P. miles* in the northern Adriatic. This northwards expansion of approximately 20 NM is a subtle, but noteworthy addition to the existing knowledge and understanding of the distribution of the devil firefish. Eddy *et al.* (2019) discuss the possibility of western Atlantic juvenile lionfish using nursery habitats such as mangroves and seagrass beds and later migrating to different habitats. The site fidelity characteristic for this species (Bottacini *et al.*, 2024) might therefore be developed in later life stages. While the possibility of this specimen's settlement being caused by larval dispersal should not be excluded, active migration could be a likely vector of the species' northwards expansion (Morris *et al.*, 2009). The seabed of Sakarun Bay is included in the Natura 2000 ecological network as the marine site HR3000069 – Uvala Sakarun, designated under the Habitats Directive for the conservation of valuable marine habitats such as *Posidonia oceanica* meadows and reefs. The detection of *P. miles* within this protected area highlights the importance of incorporating targeted monitoring of this NIS into existing management frameworks. Early detection and, where feasible, removal of individuals may help limit further spread and reduce potential impacts on native food webs and biodiversity within this ecologically valuable habitat.

Although several marine NIS have been recorded in the Adriatic Sea, many have not yet been formally classified as invasive. In the European Union, invasive NIS are regulated under Regulation (EU) No. 1143/2014, which establishes criteria for their assessment and listing. However, many marine NIS occurring in European seas, including the Adriatic, have not yet been evaluated within this framework. This is also the case for *P. miles*. Although widely regarded as invasive in parts of the Mediterranean Sea due to its rapid spread and documented ecological impacts, the species has not yet been formally classified as invasive in the Adriatic region. Nevertheless, its ongoing northward expansion highlights the need for continued monitoring and further research on its potential establishment and ecological impacts in Adriatic marine ecosystems.

Tab. 1: Morphometric measures of the analysed *Pterois miles* ***specimen.***
Tab. 1: Morfometrične meritve preiskanega primerka vrste *Pterois miles**.***

Morphometric values	**Abbreviation**	**Length (mm)**
Total length	TL	149
Standard length	SL	106.8
Body height	H	37.2
Predorsal length	PreDL	32.6
Head length	HL	34.7
Eye diameter	ED	8.4
Preorbital length	PreO	14.6
Prepectoral length	PrePL	40.3
Preventral length	PreVL	39.3
Preanal length	PreAL	73.3
Dorsal fin base length	D1L	60.2
Anal fin base length	AL	18.3
Caudal peduncle length	CPL	14.5
Caudal peduncle height	CPH	11

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OSVAJANJE SEVERA: NOVI ZAPIS O POJAVLJANJU NAVADNE PLAMENKE, *PTEROIS MILES* (BENNETT, 1828), V JADRANSKEM MORJU

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POVZETEK

Navadna plamenka, Pterois miles *(Bennett, 1828), je bila v Sredozemskem morju prvič zabeležena leta 1991, kamor je verjetno vstopila skozi Sueški prekop. Avtorji predstavljajo najsevernejšo najdbo te tujerodne ribe v Jadranskem morju od njenega prvega pojava leta 2019. Primerek so opazili med potapljanjem na vdih v zalivu Sakarun (Dugi otok, Hrvaška) junija 2025 in ulovili s podvodno puško. Nedorasli osebek je v dolžino meril 149,0 mm (standardna dolžina 106,8 mm) in tehtal 36,1 g.*

Ključne besede: plamenka, najsevernejše pojavljanje, tujerodna vrsta, zaliv Sakarun

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FIRST RECORD OF THE DEVIL FIREFISH *PTEROIS MILES* (BENNETT, 1828) (ACTINOPTERYGII: SCORPAENIDAE) FROM MALTESE COASTAL WATERS

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ABSTRACT

A specimen of the invasive Devil firefish, Pterois miles *(Bennett, 1828), was recorded for the first time in Maltese waters in January 2026. The individual was caught by a recreational angler at Migraħ Ferħa (north-west Malta) at a depth of 10 m using a paternoster rig baited with squid. The fish was photographed and then released. This record marks a further expansion of the* P. miles *distribution in the central Mediterranean Sea and highlights the importance of citizen science initiatives in the early detection of marine non-indigenous species.*

Key words: Lionfish, *Pterois miles*, Malta, Mediterranean Sea, invasive species, citizen science

PRIMA SEGNALAZIONE DEL PESCE LEONE *PTEROIS MILES* (BENNETT, 1828) (ACTINOPTERYGII: SCORPAENIDAE) DALLE ACQUE COSTIERE MALTESI

SINTESI

Un esemplare della specie invasiva Pterois miles *(Bennett, 1828), nota come pesce scorpione o pesce leone, è stato segnalato per la prima volta nelle acque maltesi nel gennaio 2026. Il pesce è stato catturato da un pescatore sportivo a Migraħ Ferħa (costa nord-occidentale di Malta) a una profondità di 10 m, utilizzando una lenza paternoster provvista di calamaro come esca. Una volta fotografato, l'esemplare è stato rilasciato. Questa segnalazione rappresenta un ulteriore ampliamento della distribuzione di* P. miles *nel Mediterraneo centrale e sottolinea l'importanza delle iniziative di scienza partecipativa per l'individuazione precoce di specie marine non-indigene.*

Parole chiave: pesce leone, *Pterois miles*, Malta, Mediterraneo, specie invasiva, scienza partecipativa

INTRODUCTION

The Devil firefish, *Pterois miles* (Bennett, 1828), is a scorpaenid fish native to the Red Sea and the Indo-West Pacific, ranging from East Africa to Indonesia (Poss & Motomura, 2022). It is equipped with highly venomous fin spines. It has become one of the most successful marine invaders worldwide, particularly following its rapid expansion in the western Atlantic (Schofield, 2009; Albins & Hixon, 2013).

In the Mediterranean Sea, *P. miles* is a Lessepsian migrant, having entered via the Suez Canal (Bariche *et al.*, 2017; Golani *et al.*, 2021). The species was first recorded in Israeli waters in 1991 (Golani & Sonin, 1992), and since the early 2010s, it has undergone a rapid range expansion across the eastern Mediterranean, with records from the waters of Lebanon and Cyprus (Bariche *et al.*, 2013; Iglésias & Frotté, 2015), Turkey (Turan *et al.*, 2014), Greece (Crocetta *et al.*, 2015), Israel (Stern & Rothman, 2019), and as far as the central sector of the Tunisian coasts (Dailianis *et al.*, 2016), demonstrating its highly invasive character in the eastern part of the basin (Kletou *et al.*, 2016; Azzurro *et al.*, 2017; Katsanevakis *et al.*, 2020; Kondylatos *et al.*, 2023, 2024). More recently, the species has continued to spread westward, with records from the Ionian Sea, the Adriatic, and Sicily indicating ongoing colonisation of central Mediterranean ecosystems (Azzurro *et al.*, 2022, 2025). The species is also familiar to spearfishers in Libya and Tunisia (Al Mabruk & Rizgalla, 2019; Ben Amor *et al.*, 2022). Although still unpublished at the time of writing, another Mediterranean record of the species was reported on social media on 26 April 2026 by Manuela Falautano and ISPRA (the national Italian institute for environmental management) from the Italian island of Lampedusa, located in the Strait of Sicily just over 100 km south-west of the Maltese Islands.

Despite its proximity to colonised areas, no confirmed published records of *P. miles* from Maltese waters have been documented to date. In fact, when SCUBA diving centres in Malta and neighbouring countries were consulted as part of a pan-Mediterranean study, they stated that they had observed the species in local waters but did not provide any photographic or video evidence of such occurrences, raising doubts of misidentification (Bottacini *et al.*, 2024). Here, we report the first occurrence of *P. miles* in Malta based on photographic evidence provided by a recreational angler.

MATERIAL AND METHODS

On 27 April 2026, a Maltese angler contacted one of the authors (A.D.) through the “Spot the Alien” citizen science campaign (campaigns.ocean.mt) to report a lionfish caught on 25 January 2026. The observation involved a single lionfish, captured using a paternoster rig with size 10 hooks baited with squid (Fig. 1). The capture took place from land at a depth of approximately 10 m at Migraħ Ferħa, northwest Malta Island (35°52’25.0”N, 14°20’36.3”E), on a rocky substrate.

The fish was photographed immediately after capture. No morphometric measurements nor meristic counts were taken, as the individual was released alive shortly afterwards.

Species identification was based on morphological characteristics and colour visible in the photograph, while some biometric measurements were estimated using ImageJ software (Schindelin *et al.*, 2012). Before measurement, the image was calibrated using a reference object of known dimensions visible in

Fig. 1.: The individual of* Pterois miles *fished at Migraħ Ferħa, Malta Island, on 25 January 2026 (Photo by James Mamo).
Sl. 1.: Primerek plamenke* (Pterois miles)*, ujet pri mestu Miġraħ Ferħa na otoku Malta 25. januarja 2026 (Fotografija: James Mamo).

the photograph (*i.e.*, the fisherman's hand), allowing conversion of pixel values to centimetres. Standard morphometric parameters were then recorded where possible, including total length (TL), standard length (SL), head length, eye diameter, caudal fin length, and pre-dorsal and pre-pectoral distances. Measurements were taken along straight-line axes using the segmented line and point tools in the software. To minimise potential error associated with image perspective and fish curvature, only clearly defined anatomical landmarks and axes aligned as closely as possible to the plane of the image were used.

RESULTS

The photographed fish (Fig. 1) was identified as *P. miles* following Schultz (1986), Poss (1999), Golani *et al*. (2021), and Poss & Motomura (2022). The pectoral fin does not extend beyond the caudal peduncle; the head and body have a pale background and dark red or reddish brown vertical bars of irregular width; four broad stripes radiate from the eyes; the supraocular cirrus is blackish; dorsal-fin spines have dark red areas alternating with nearly white areas; soft dorsal, anal, and caudal rays have numerous black spots, and the membranes are transparent. Estimated morphometric measurements obtained from the lateral photographic analysis were: total length (TL) 13.8 cm; standard length (SL) 10.5 cm; head length 4.1 cm (39.0% of SL); eye diameter 0.9 cm (8.6% of SL); caudal fin length 3.3 cm; pre-dorsal distance 3.8 cm (36.2% of SL); pre-pectoral distance 3.4 cm (32.4% of SL).

DISCUSSION

This record represents the first documented occurrence of *Pterois miles* in Maltese waters and contributes to the growing body of evidence indicating the species' rapid expansion across the central Mediterranean Sea.

Morphological characters and colour of the Maltese individual agreed with the literature mentioned above and allowed for its identification as *P. miles*. The rocky substrate and shallow depth of capture are consistent with habitat preferences observed for the species in invaded Mediterranean areas, where individuals frequently occupy rocky reefs and coastal habitats between 5 and 50 m depth (Kletou *et al*., 2016; Kondylatos *et al*., 2023).

The arrival of *P. miles* in Malta is not entirely unexpected given its established presence in nearby regions such as Sicily and the Ionian and Adriatic seas, as well as in Libyan and Tunisian waters (Azzurro *et al*., 2017, 2025; Di Martino *et al*., 2021; Dulčić *et al*., 2024). A high degree of hydrodynamic connectivity and larval dispersal likely facilitate this continued spread (Johnston & Purkis, 2015). Nevertheless, the 'late' nature of this sighting might be putatively attributed to the discarding at sea of specimens caught by local fishers wary of its venomous nature or to the non-use of underwater cameras by SCUBA diving instructors during supervised dives with customers. The dispersion pathway for the *P. miles* specimen recorded in this study might have proceeded along the North African coastline and the Tunisian platform, as hypothesized for similar newcomers such as *Sepioteuthis lessoniana* (Marrone *et al*., 2025). In addition, several mathematical modelling studies (*e.g.,* Turan, 2020; Mitchell & Dominguez Almela, 2025) have predicted that the north-eastern stretches of the African coast, as well as central Mediterranean areas, including the waters around Malta, provide the most suitable areas for lionfish establishment.

The ecological implications of this record are significant. Lionfish are generalist predators with high reproductive output and few natural predators in invaded ecosystems, allowing them to exert strong predation pressure on native fish and invertebrate assemblages (Albins & Hixon, 2013; Zannaki *et al*., 2019; Batjakas *et al*., 2023). Their establishment in Maltese waters could therefore pose a threat to local biodiversity and fisheries resources.

It is important to note that the fish was released alive after capture, raising the possibility of future recapture. Moreover, the presence of additional individuals in the area cannot be excluded. Public awareness and targeted removal efforts have been identified as key management strategies in other regions (Azzurro *et al*., 2022). In reviewing management lessons learned from the lionfish invasion of the western Atlantic, Ulman *et al.* (2022) listed participatory management, involving local stakeholders and organisations, as a key strategy, along with a number of others (*e.g.*, lionfish hunting tourism, recreational tournaments and commercial fishery removals). Removal experiments involving the two highly invasive species, *Pterois miles* and *Diadema setosum*, were carried out in Cyprus, and their effectiveness in reducing their populations and facilitating the recovery of native fish populations was discussed (Hüseyinoğlu *et al.,* 2024). Within participatory management strategies, citizen science campaigns play a critical role in detecting early-stage invasions through an early-warning system. Platforms such as "Spot the Alien" provide valuable real-time data that can kick-start and complement scientific monitoring programs.

Further monitoring is required to determine whether this record represents an isolated occurrence or the early stage of population establishment in Maltese waters.

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PRVI ZAPIS O POJAVLJANJU PLAMENKE *PTEROIS MILES* (BENNETT, 1828) (ACTINOPTERYGII: SCORPAENIDAE) V MALTEŠKIH OBALNIH VODAH

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POVZETEK

Avtorji poročajo o invazivni plamenki, Pterois miles *(Bennett, 1828), ki je bila januarja 2026 prvič zabeležena v malteških vodah. Primerek te vrste je ujel ljubiteljski ribič pri mestu Miġraħ Ferħa (severozahodna Malta) na globini 10 metrov z uporabo ribiške vrvice s svincem na dnu (paternoster), kot vabo pa je uporabil lignja. Riba je bila fotografirana in nato izpuščena. Ta zapis o pojavljanju označuje nadaljnjo* širitev *območja razširjenosti vrste* P. miles *v osrednjem Sredozemskem morju in poudarja pomen pobud ljubiteljske znanosti pri zgodnjem odkrivanju tujerodnih morskih vrst.*

Ključne besede: plamenka, *Pterois miles*, Malta, Sredozemsko morje, invazivna vrsta, ljubiteljska znanost

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FIRST MEDITERRANEAN RECORD OF THE DIAGONAL BUTTERFLYFISH, *CHAETODON FASCIATUS* FORSSKÅL, 1775, REPORTED FROM SYRIAN WATERS

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ABSTRACT

The present study reports the first occurrence of the diagonal butterflyfish, Chaetodon fasciatus*, in the Mediterranean Sea, based on a specimen recorded in Syrian waters. A single individual (145 mm total length) was caught on 25 October 2025 in the shallow waters off the coast of Latakia. The pathway of introduction of this species, which is native to the Red Sea and the Gulf of Aden, remains unclear and requires further investigation. The increasing number of non-indigenous fish species of Indo-Pacific/Red Sea origin recorded in the region highlights the need for a comprehensive strategy for marine biodiversity conservation.*

Key words: non-indigenous species, Lessepsian migration, *Chaetodon fasciatus*, Mediterranean Sea, Syria

PRIMA SEGNALAZIONE MEDITERRANEA DEL PESCE FARFALLA FASCIATO, *CHAETODON FASCIATUS* FORSSKÅL, 1775, DALLE ACQUE SIRIANE

SINTESI

Il presente studio riporta la prima segnalazione del pesce farfalla fasciato, Chaetodon fasciatus*, nel mare Mediterraneo, sulla base di un esemplare ritrovato nelle acque siriane. Un singolo individuo (145 mm di lunghezza totale) è stato catturato il 25 ottobre 2025 nelle acque poco profonde al largo della costa di Lattakia. La modalità di introduzione di questa specie, originaria del mar Rosso e del Golfo di Aden, rimane poco chiara e richiede ulteriori indagini. Il numero crescente di specie ittiche non indigene di origine indo-pacifica/mar Rosso registrate nella regione evidenzia la necessità di una strategia globale per la conservazione della biodiversità marina.*

Parole chiave: specie non indigene, migrazione lessepsiana, *Chaetodon fasciatus*, Mediterraneo, Siria

INTRODUCTION

The biological composition of the eastern Mediterranean is being altered through progressive settlement of non-indigenous species, a process that is enhanced by global climate change and anthropogenic activities (Khalil *et al.*, 2025). The primary introduction pathways of alien species include the Suez Canal (Lessepsian migration from the Red Sea), followed by maritime transport, aquaculture, and aquarium release (Zenetos *et al.*, 2016). While establishing populations and colonising their new habitats, newcomers often exhibit invasive behaviour (Cosentino & Caruso, 2025). Species of the family Chaetodontidae (Acanthuriformes), commonly known as the butterflyfish, are distributed in tropical and warm-temperate seas worldwide, but are primarily concentrated in the Indo-West Pacific, extending up to the Gulf of Aden and the Red Sea (Heemstra & Heemstra, 2022; Froese & Pauly, 2025). Members of this family are characterised by a compressed, deep body and a continuous dorsal fin, with a small, terminal, and protrusible mouth adapted for feeding on small invertebrates and coral polyps (Bellwood *et al.*, 2010). Most species display bright coloration, with many exhibiting distinctive patterns such as dark stripes or bands across the body, often accompanied by a dark eye-band and an eyespot on the dorsal fin (Fischer & Bianchi, 1984; Kelley *et al.*, 2013).

Previously, five species of Chaetodontidae, all non-indigenous, were recorded in the Mediterranean Sea. Four of these are native to the Red Sea – *Chaetodon auriga* Forsskål, 1775, *Chaetodon austriacus* Rüppell, 1836, *Chaetodon larvatus* Cuvier, 1831, and *Heniochus intermedius* Steindachner, 1893 (Kovačić *et al.*, 2021; Froese & Pauly, 2025) – while the fifth species, *Chaetodon hoefleri* Steindachner, 1881, naturally occurs in the eastern Atlantic (Ayari-Kliti, 2025). The species examined in the present study, the diagonal butterflyfish, *Chaetodon fasciatus* Forsskål, 1775, also known as the Red Sea raccoon butterflyfish, is a chaetodontid species distributed throughout the Red Sea, including the Gulfs of Suez, Aqaba, and Aden (Lieske & Myers, 1997; Golani & Fricke, 2018).

This study documents the finding of *C. fasciatus* in Syrian waters and represents the first record of the species in the entire Mediterranean Sea.

MATERIAL AND METHODS

On 25 October 2025, an individual of *C. fasciatus* was caught using a hook, at a depth between 5 and 15 m over a rocky substrate, in the waters off the city of Latakia, Syria (35°31′5.97″N, 35°42′48.57″E, Fig. 1). Morphometric measurements of length (to the nearest mm) and weight (to the nearest g) were recorded, and meristic counts were performed. The specimen was then photographed, preserved in 7% formaldehyde, and deposited as a reference sample (HIMR-2025-Chf) at the fisheries laboratory of the High Institute of Marine Research, Lattakia University (Lattakia, Syria). Species identification was conducted following Lieske & Myers (1997), Khalaf & Disi (1997), and Heemstra & Heemstra (2022).

RESULTS AND DISCUSSION

The specimen of *C. fasciatus* captured off the coast of Latakia (Fig. 2) measured 145 mm total length and weighed 62.8 g. It exhibited a deep, compressed body, a slightly narrow protrusible snout, large eyes, a continuous dorsal fin, and a rounded caudal fin. The dorsal and anal fins reached the base of the caudal peduncle. The fin formula of the specimen is: D, XII+25; P, 25; A, III+18; C, 16 (ventral fins were deteriorated) The ground colour was predominantly yellow, with a black patch

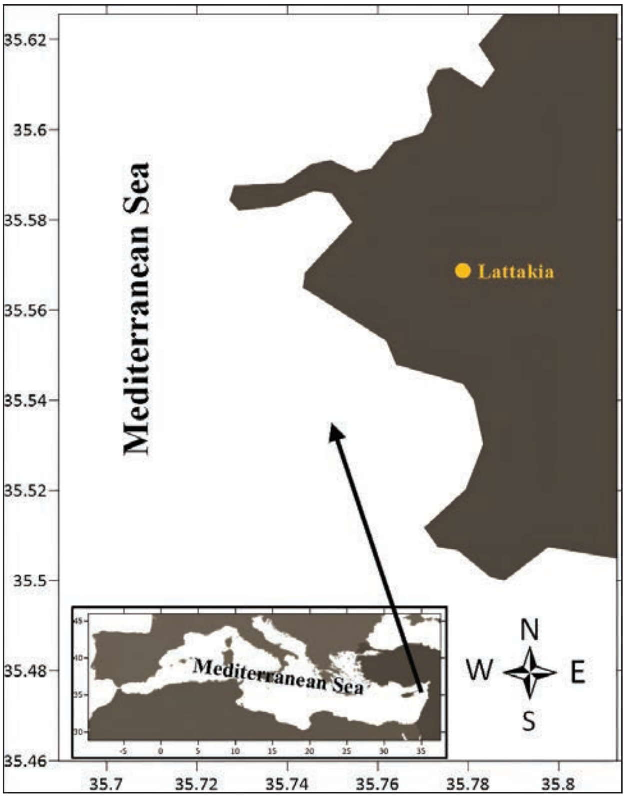

Fig. 1: Map showing the capture site of the *Chaetodon fasciatus* ***specimen collected off the coast of Latakia, Syria.***

Sl. 1: Zemljevid obravnavanega območja z lokaliteto ulova primerka vrste *Chaetodon fasciatus* ***ob obali Latakie, Sirija.***

Fig. 2: Specimen of *Chaetodon fasciatus* ***caught off the city of Latakia, Syria.***
Sl. 2: Primerek vrste *Chaetodon fasciatus****, ujet v vodah ob mestu Latakia, Sirija.***

covering the eyes and the anterior of the head, and a white patch above it. Additional markings included a black patch below the anterior portion of the dorsal fin, a dark line at the base of the dorsal fin, dark outer margins of the dorsal and anal fin spines, dark lines along the outer edges of the soft dorsal and anal fins, extending across the caudal fin, dark oblique lines on the body, oriented slightly backward and upward, with the uppermost line wider than the rest. A dark patch seemed to join the seven upper black oblique lines posteriorly. These morphological characteristics, measurements, and proportions (Tab. 1), as well as meristic counts were in agreement with those reported for *C. fasciatus* by Lieske & Myers (1997), Khalaf & Disi (1997), and Heemstra & Heemstra (2022). In particular, the distinctive colour pattern of the specimen from Syrian waters confirmed its identification as *C. fasciatus*, clearly distinguishing it from all other congeners from the Red Sea and the western Indian Ocean (Heemstra & Heemstra, 2022).

The finding of *C. fasciatus* in Syrian waters reported here represents the first record of this species in the Mediterranean Sea (Froese & Pauly, 2025). It is the third species of the family Chaetodontidae recorded in the coastal waters of Syria, after *C. larvatus* (Ali *et al.*, 2017) and *H. intermedius* (Ibrahim *et al.*, 2022; Saad *et al.*, 2022). This finding adds a new non-indigenous record to the already documented 82 fish species of Indo-Pacific/Red Sea origin (Saad *et al.*, 2022), as well as to the 50 non-indigenous fish species from neighbouring seas recorded in Syrian marine waters between 2018 and 2025. The vast majority of these species are believed to have arrived through the Suez Canal (Ibrahim *et al.*, 2025; Ibrahim *et al.*, 2026).

In its natural distribution range, *C. fasciatus* inhabits lagoons, fringing reefs, and coral reef flats at depths of up to approximately 25 m, usually in pairs, but occasionally also in aggregations of up to 15 individuals. Feeding on coral polyps, algae, and benthic invertebrates, *C. fasciatus* can grow to a maximum total length of 250 mm, through commonly reaching 150 mm (Heemstra & Heemstra, 2022; Froese & Pauly 2025).

Being our record based on a single specimen, it is unclear whether this represents a truly new and recent arrival. It is possible that the species was already present in the area, but remained undetected due to its scarcity, overlooked by fishermen because of its small size and low commercial value, or absent from fishery catches due to its preference for very shallow habitats, which limits encounters with commercial fishing gears.

The lack of natural environmental barriers that could limit migration from the Red Sea to the Mediterranean, combined with increased human commercial activity – especially following the Suez Canal expansion in 2015 – may have played a key role in facilitating the arrival

Tab 1: Morphometric measurements and their proportions (expressed as % of standard length) of *Chaetodon fasciatus* ***caught off Latakia coast, Syria.***
Tab. 1: Morfometrične meritve in deleži (izraženi kot % standardne dolžine) primerka vrste *Chaetodon fasciatus****, ujetega ob obali Latakie, Sirija.***

Characteristics	Measurement (mm)	% SL
Total length	145	
Standard length (SL)	117	
Body depth	95	81.2
Head length	33	28.2
Eye diameter	10	8.5
Snout length	8	6.8
Dorsal fin length	95	81.2
Pectoral fin length	30	25.6
Pelvic fin length	32	27.3
Caudal fin length	25	21.4
Anal fin length	50	42.7
Caudal peduncle distance	12	10.2
Distance before dorsal fin	47	40.1
Distance before pectoral fin	36	30.7
Distance before anal fin	85	72.6

of new Red Sea fish species in the basin (Ibrahim *et al.*, 2022). Nevertheless, as *C. fasciatus*, like many other chaetodontids, is a popular ornamental marine fish (Froese & Pauly, 2025), accidental aquarium release in the area cannot be ruled out.

As underlined above, the record documented in the present study is based on a single specimen. Therefore, the successful establishment of *C. fasciatus* in the area remains to be confirmed through additional records from nearby regions, which would also help clarify the species' introduction pathway. In any case, the presence of this tropical fish species in Syrian waters provides strong evidence that, due to climate change and sea warming, the eastern Mediterranean region currently exhibits environmental conditions suitable for tropical and warm-water fish species (Ibrahim *et al.*, 2020, 2022). This finding highlights the urgent need for monitoring biodiversity changes in the region to mitigate any negative impacts associated with such ecological shifts.

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PRVI SREDOZEMSKI ZAPIS O POJAVLJANJU POŠEVNOPROGASTE ŠČETINOZOBKE, *CHAETODON FASCIATUS* FORSSKÅL, 1775, IZ SIRSKIH VODA

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POVZETEK

Avtorji poročajo o prvem pojavljanju poševnoprogaste ščetinozobke, Chaetodon fasciatus*, v Sredozemskem morju na podlagi primerka, zabeleženega v sirskih vodah. Primerek (skupne dolžine 145 mm) je bil ujet 25. oktobra 2025 v plitvini ob obali Latakie. Način pojava te vrste, ki je samonikla v Rdečem morju in Adenskem zalivu, ostaja nejasna in zahteva nadaljnje raziskave. Naraščajoče število tujerodnih vrst rib indopacifiškega/rdečemorskega izvora, zabeleženih v regiji, narekuje potrebo po celoviti strategiji za ohranjanje morske biotske raznovrstnosti.*

Ključne besede: tujerodne vrste, lesepska selitev, *Chaetodon fasciatus*, Sredozemsko morje, Sirija

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A FURTHER RECORD OF THE BARRED KNIFEJAW, *OPLEGNATHUS FASCIATUS* (TEMMINCK & SCHLEGEL, 1844), A PACIFIC SPECIES, FROM THE MEDITERRANEAN: A NEW RECORD FROM BENGHAZI, LIBYA

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ABSTRACT

The occurrence of the barred knifejaw, Oplegnathus fasciatus*, has been documented for the first time in Libyan waters, south Mediterranean Sea. This species is native to the Northwestern and central-eastern Pacific and its presence in the Mediterranean has been reported through previous scattered records. A single specimen was captured on 3 February 2023 of the coast of Benghazi at a depth of approximately 12 m using a trammel net. Both morphological and meristic examinations as well as a genetic validation via the mitochondrial COI gene were used for species identification. This report discusses the potential pathways for the species' arrival in the southern Mediterranean. A key forthcoming objective is to leverage citizen science, enhancing public awareness and improving the capacity for early detection of alien species.*

Key words: non-indigenous species, mitochondrial COI, Oplegnathidae, shipping

ULTERIORE SEGNALAZIONE DEL PESCE PAPPAGALLO GIAPPONESE (*OPLEGNATHUS FASCIATUS* (TEMMINCK & SCHLEGEL, 1844)), SPECIE DEL PACIFICO, NEL MEDITERRANEO: NUOVA OSSERVAZIONE A BENGASI, LIBIA

SINTESI

La presenza del pesce pappagallo giapponese, Oplegnathus fasciatus*, è stata documentata per la prima volta nelle acque libiche del Mediterraneo meridionale. Specie originaria del Pacifico nord-occidentale e centro-orientale, era già stata segnalata sporadicamente nel Mediterraneo. Un esemplare è stato catturato il 3 febbraio 2023 al largo di Bengasi, a circa 12 m di profondità, mediante rete da imbrocco-tramaglio. L'identificazione è stata confermata tramite analisi morfologiche, meristiche e genetiche del gene mitocondriale COI. Lo studio discute le possibili vie di introduzione della specie nel Mediterraneo meridionale e sottolinea l'importanza della scienza partecipativa per aumentare la consapevolezza pubblica e favorire l'individuazione precoce delle specie aliene.*

Parole chiave: specie non-indigene, COI mitocondriale, Oplegnathidae, trasporto marittimo

INTRODUCTION

The Mediterranean Sea is widely recognized as a global hotspot for marine bio-invasions (Rilov & Galil, 2009; Edelist *et al.*, 2013). It stands as the world's most invaded marine basin, with non-indigenous species (NIS) now representing nearly every major taxonomic group, including fishes (Streftaris *et al.*, 2005; Azzurro *et al.*, 2022a; Galanidi *et al.*, 2023). Considering fishes, in recent decades, at least 188 fish species have been introduced into the basin with an accelerating pace that has triggered significant environmental, social, and economic consequences (Azzurro *et al.*, 2022b). Most of these introduced fishes originate from the Red Sea/Indo-West Indian Ocean and entered into the Mediterranean via the human-made Suez Canal, other species entered through natural range expansion from the eastern Atlantic via the Strait of Gibraltar, while other arrived via direct and indirect human-mediated transport such as aquaculture, the aquarium trade, and shipping, generally from regions far from the eastern Atlantic or the Red Sea/Indo-West Indian Ocean (Galil, 2007; Katsanevakis *et al.*, 2014; Golani *et al.*, 2021; Azzurro *et al.*, 2022b).

Within this context, the Libyan coastline remains one of the Mediterranean's least-explored regions (Coll *et al.*, 2010). Its native fish fauna is still poorly documented (Quignard & Tomasini, 2000; Elbaraasi *et al.*, 2019), and records of non-indigenous fishes appear to date limited (Nour *et al.*, 2022).

The barred knifejaw, *Oplegnathus fasciatus* (Temminck & Schlegel, 1844) (Oplegnathidae), is a benthopelagic species indigenous to rocky reefs in the Northwest Pacific (Japan, Korea, China) and the Eastern Pacific (Hawaii) (Nakabo, 2002). The occurrence of this species has recently been documented beyond its native range, including the Pacific coast of North America. Its initial arrival in North America is linked to the 2011 Japanese earthquake and tsunami, whose transoceanic debris is believed to have transported specimens, leading to subsequent observations in Washington, Oregon, and California waters. In the Mediterranean Sea, this species was reported from Malta (Schembri *et al.*, 2010), from Italy and the Adriatic Sea (Ciriaco & Lipej, 2015), and Dulčić *et al.* (2016) from the Adriatic Sea. These occurrences underscore the species' capacity for long-distance dispersal via ocean rafting on marine debris, highlighting a significant mechanism for invasive species expansion beyond their historical boundaries (Ta *et al.*, 2018). Reaching a maximum length of 80 cm and a weight of 6.4 kg in its natural range, it preys chiefly on hard-shelled invertebrates like crustaceans and mollusks. Juveniles are strongly associated with floating objects; they are a dominant species found with drifting seaweed and have been recorded accompanying oceanic debris. The barred knifejaw is of commercial importance, supports aquaculture operations, and is valued as a game fish (Nakabo, 2002; Schembri *et al.*, 2010; Froese & Pauly, 2026).

This work documents the first finding of the barred knifejaw, *O. fasciatus*, from Libyan waters, south Mediterranean Sea, and discusses the potential pathways of its introduction.

MATERIAL AND METHODS

On 3rd February 2023, a single subadult *Oplegnathus fasciatus* was captured in a trammel net set at a depth of approximately 12 meters off the coast of Benghazi (32.1194° N, 20.0868° E), Libya (Fig. 1) alongside various demersal fish species like *Pagellus erythrinus*, *Diplodus sargus*, and *Mullus surmuletus*. The specimen was immediately placed on ice and transported to the Aquaculture and Fisheries Laboratory within the Department of Zoology, Faculty of Science, University of Benghazi.

In the laboratory, the specimen was photographed, and standard morphometric and meristic analyses were conducted (Fig. 2). It was measured to the nearest mm and weighed to the nearest 0.1 g. The individual was identified based on its distinctive pattern of light and dark vertical bands, following the taxonomic key of Nakabo (2002). Finally, the specimen was preserved and accessed into the Museum Collection of the Department of Zoology, University of Benghazi under the catalogue number Z9388.

A tissue sample was excised from the caudal fin using sterilized scissors and preserved in 95% ethanol for genetic analysis. At the genetics laboratory, DNA was amplified using the cytochrome c oxidase subunit I (COI)

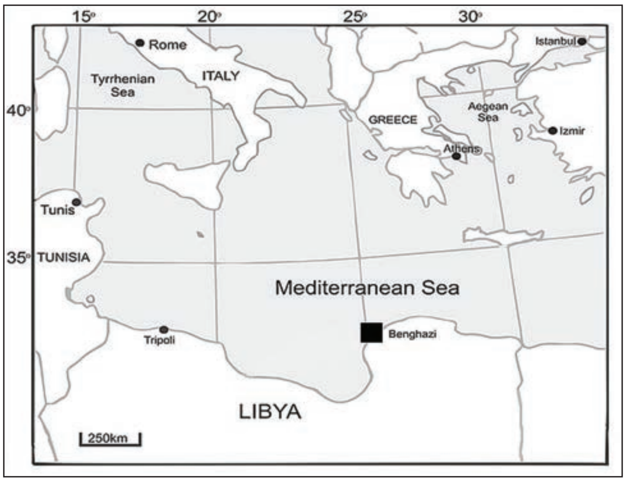

Fig. 1: Capture location of *Oplegnathus fasciatus* **(141 mm TL) off the coast of Benghazi, Libya (32.1194 N, 20.0868 E). Black square showing the locality of the fish collection.**

Sl. 1: Zemljevid obravnavanega območja z lokacijo ulova cunami ribe (141 mm TL) ob obali Bengazija v Libiji (32.1194 S, 20.0868 V). Črn kvadrat prikazuje mesto vzorčenja (ulova) ribe.

gene primers described by Ward *et al.* (2005): forward 5′-TCAACCAACCACAAAGACATTGGCAC-3′ and reverse 5′-TCGACTAATCATAAAGATATCGGCAC-3′. The resulting consensus sequence was deposited in the GenBank database under accession number PX317154.

For phylogenetic reconstruction, 11 additional COI sequences for *O. fasciatus* were downloaded from GenBank, along with three sequences from related species as outgroups. All sequences, including the Libyan sample, were trimmed to a uniform length of 534 bp. Phylogenetic trees (Maximum Likelihood (ML) and Neighbour-Joining (NJ)) were constructed using MEGA v10.0.5. The ML tree was built using the Kimura 2-parameter model to calculate genetic distances, while the NJ tree was constructed using the Maximum Composite Likelihood model. Branch support for both trees was assessed with 1,000 bootstrap replicates.

RESULTS AND DISCUSSION

The specimen measured 141 mm in total length and weighed 66.3 g. Table 1 presents a comparison of its principal morphometric and meristic characteristics with those of specimens from other geographic regions.

The body is relatively deep and laterally compressed, tapering to a small head with a pointed snout (Fig. 2). The mouth is small and terminal, with the jaw failing to extend to the anterior margin of the eye. The operculum bears a single spine, while the preopercular margin is distinctly serrated. A single dorsal fin is present, marked by a deep notch separating the spinous anterior portion from the soft-rayed posterior section; the membranes between the spines exhibit a pronounced incision. The anal fin is triangular, and the caudal fin is truncated with rounded lobes. The body is uniformly covered with small ctenoid scales.

The coloration consists of seven bold, black vertical bars set against a bluish-grey background. The first band is through the eye, followed by four bars approximately equal in width to the pale intervals separating them, while the final two bars are narrower, one on the caudal peduncle and one at the base of caudal fin (Fig. 2). The soft-rayed portions of the dorsal and anal fins, along with the entirety of the pelvic fins, as well as the outer portion of caudal fin are jet black. Pectoral fin is transparent.

The Maximum Likelihood (ML) phylogenetic tree based on a 534-bp fragment of the mitochondrial COI gene (Fig. 3) revealed that the Libyan *O. fasciatus* sample (PX317154) clustered with specimens from East Asia, specifically Japan, South Korea, and Taiwan. All *O. fasciatus* sequences formed a well-differentiated, coherent cluster that was clearly distinct from the outgroup species (*Kyphosus sydneyanus* and *Acanthistius* spp.). A Neighbour-Joining (NJ) tree constructed from the same dataset showed a nearly identical topology, with the Libyan sequence again grouping with those from East Asia. In both analyses, the outgroup taxa were positioned outside the *O. fasciatus* cluster.

Following Golani *et al.* (2021), the barred knifejaw, *O. fasciatus* is distinguished from *Abudefduf spp.* by its seven vertical bars, in contrast to the five typically found in the latter, while species within the families Scaridae, Tetraodontidae, and Diodontidae are easily differentiated from *O. fasciatus* by their complete lack of vertical body bars. The total length (141 mm) falls within the Mediterranean range (140 mm Malta, Schembri *et al.*, 2010) estimated 140 mm in Italian Adriatic, Ciriaco & Lipej, 2015, 100 mm Croatia, Dulčić *et al.*, 2016). This similarity among Mediterranean specimens reflects a comparable

Fig. 2:** Oplegnathus fasciatus* ***specimen (141 mm TL) collected off the coast of Benghazi, Libya, in the southern Mediterranean Sea (Photo by H. Elbaraasi).
Sl. 2: Primerek cunami ribe (141 mm TL), ulovljen ob obali Bengazija v Libiji v južnem Sredozemskem morju (Fotografija: H. Elbaraasi).

Tab. 1: Biodata of specimen of* Oplegnathus fasciatus *caught in the Libyan coast of the Mediterranean Sea at the coast of Benghazi City.

Tab. 1: Biološki podatki o primerku vrste* Oplegnathus fasciatus *(cunami riba), ulovljenem ob libijski obali Sredozemskega morja blizu mesta Bengazi.

Morphometric (mm)/ Meristic characters	**Present study**	**Jordan & Fowler (1902)**	**Schembri *et al*. (2010)**	**Ciriaco & Lipej (2015)**	**Dulčić *et al*. (2016)**
Total length (TL)	141	-	130, 200	140	100
Standard length (SL) (% in TL)	120 (85.1)	-	-	-	75(75%in TL)
Head length HL (%SL)	41 (34.2)	-	-	-	27 (27% in TL)
Eye diameter (%HL)	8 (19.5)	-	-	-	8 (29.65in HL)
Preorbital length (%HL)	9 (22)	-	-	-	8 (29.6% in HL)
Postorbital length (%HL)	18 (43.9)	-	-	-	12 (44.4% in HL)
Interorbital distance (%HL)	10 (24.4)	-	-	-	7 (25.9% in HL)
Predorsal length (%SL)	39 (32.5)	-	-	-	32(32% in TL)
Length of dorsal fin base (%SL)	75 (62.5)	-	-	-	51 (51% in TL)
Prepelvic length (%SL)	47 (39.2)	-	-	-	32 (32% in TL)
Preanal length (%SL)	87 (72.5)	-	-	-	54 (54% in TL)
Length of anal fin (%SL)	35 (29.2)	-	-	-	22 (22% in TL)
Length of pectoral fin (%SL)	26 (21.7)	-	-	-	18 (18% in TL)
Length of pelvic fin (%SL)	27 (22.5)	-	-	-	19 (19% in TL)
Body depth (%SL)	69 (57.5)	-	-	-	47 (47% in TL)
Depth of caudal peduncle (%SL)	17 (14.2)	-	-	-	9 (9% in TL)
Total weight (g)	66.3	-	-	-	18.1 18.1% in TL)
Dorsal fin spine and ray counts	XII, 15	XI-XII, 17-18	-	-	XII, 16
Pectoral fin ray count	15	I, 16	-	-	18
Anal fin ray count	III, 13	III, 12-13	-	-	III, 13
Pelvic fin ray count	I, 5	I, 5	-	-	I, 5
Caudal fin ray count	14	-	-	-	15

juvenile ontogenetic stage, recent introduction history (early 2000s), and possible sampling bias toward smaller individuals (Schembri *et al.*, 2010; Froese & Pauly, 2026). The difference from the native range is due to ontogenetic maturity—the 700 mm specimen is a fully grown adult—and the Mediterranean population's early establishment stage, lacking sufficient time or conditions to reach large sizes (Froese & Pauly, 2026).

Several morphometric proportions showed close agreement with the Croatian specimen (Dulčić *et al.*, 2016), including postorbital length (43.9% vs. 44.4% HL) and interorbital distance (24.4% vs. 25.9% HL), reflecting developmental stability, low environmental sensitivity, and genetic constraint (Nakabo, 2002; Froese & Pauly, 2026). Eye diameter varied (19.5% vs. 29.6% HL), which is best explained by allometric growth, smaller juveniles have proportionally larger eyes (He *et al.*, 2012), along with measurement methodology differences and natural intraspecific variation.

The meristic counts of the Libyan specimen (Table 1) generally aligned with native range records (Jordan & Fowler, 1902) reflecting genetic stability and developmental canalization (Froese & Pauly, 2026). Slight deviations—15 pectoral rays vs. 16, and 15 dorsal soft rays vs. 16–17—are unlikely to indicate taxonomic distinction and are attributable to intraspecific variation (1–2 ray difference is common), counting errors, fin regeneration or damage, specimen size, and geographic clines such as Jordan's Rule (Jordan, 1891; He *et al.*, 2012; Froese & Pauly, 2026).

Phylogenetic reconstruction of *O. fasciatus* using 534 bp of the mitochondrial COI gene, via both maximum likelihood and Neighbour-Joining methods (Fig. 3), indicates limited genetic divergence. The analyses place the Libyan sample within a cohesive group comprising East Asian specimens from Japan, South Korea, and Taiwan, failing to support a deeply isolated lineage. In contrast, broader phylogeographic studies (Chen *et al.*, 2017) have documented three major, well-differentiated mtDNA clades across northern and

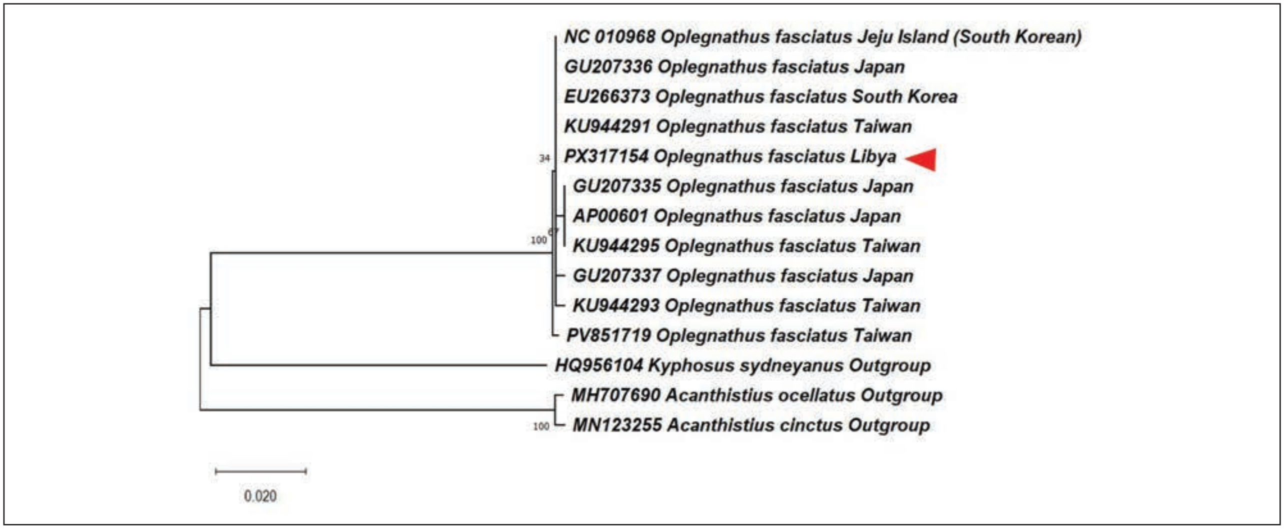

Fig. 3: A maximum likelihood phylogenetic tree, based on 534 bp of the mitochondrial COI gene, shows the relationships among* Oplegnathus fasciatus *samples from East Asia and Libya. The red arrow indicates the Libyan sample. Outgroup species include* Kyphosus sydneyanus *and two species of* Acanthistius*. Bootstrap values (expressed as percentages) are shown at the nodes.

Sl. 3: Filogenetsko drevo po metodi največjega ujemanja, zasnovano na 534 baznih parih (bp) mitohondrijskega gena COI, prikazuje sorodstvene odnose med vzorci vrste* Oplegnathus fasciatus *iz Vzhodne Azije in Libije. Rdeča puščica označuje libijski vzorec. Zunanje skupine (outgroup) vključujejo vrsto* Kyphosus sydneyanus *in dve vrsti iz rodu* Acanthistius*. Na vozliščih so prikazane vrednosti 'bootstrap' (izražene v odstotkih).

southern China, attributed to historical biogeographic barriers and subsequent population expansions.

Since the known Pacific Ocean native range of *O. fasciatus* is at a great distance from the Mediterranean, transport due to human activity, mainly shipping, was considered as the most plausible explanation for the introduction of the species in the waters of Malta and later in the North Adriatic Sea (Schembri *et al.*, 2010; Dulčić *et al.*, 2016; Golani *et al.*, 2021). Due to the scarce number of records in the Mediterranean and the large distance between them, to date it is unknown if the species was able to successfully colonize some Mediterranean regions, allowing the dispersion of individuals in other areas (Azzurro *et al.*, 2022b). This fish lives in shallow waters and being the juvenile aspect easy distinguishable from other native or introduced species, it is unlikely that other individuals were undetected or neglected by fishermen.

Thus, on the basis of the current knowledge, the occurrence of one sub-adult barred knifejaw *O. fasciatus* in Libyan waters is likely due to another independent introduction through human activities such as shipping, that have enabled this Pacific species to traverse the globe and to be released into the wild in the Mediterranean. The literature gives examples of introductions via shipping as a vector for long-distance translocations of fish like the present case (*e.g.*, Mastrototaro *et al.*, 2007; Goren *et al.*, 2009; Insacco & Zava, 2017; Azzurro *et al.*, 2022b). On the other hand, as already mentioned above, it is unknown whether established populations of the species exist in the basin. If exist, we cannot exclude that juveniles associated with floating objects or drifting seaweeds or debris arrived at Libyan waters.

The complexity of the environmental management of introduced species is a pressing concern, especially since the Libyan Mediterranean coast lacks dedicated research to evaluate the impacts of alien fishes on native ecosystems. This is compounded by an insufficiency of ongoing monitoring programs in critical zones, such as major ports, which are recognized hotspots for the introduction of non-indigenous organisms. Consequently, a key forthcoming objective is to leverage citizen science to raise public awareness and improve the probability of detecting non-indigenous species along areas where the capacity for conventional scientific monitoring surveys is still in its nascent state (*e.g.* north African – Nour *et al.*, 2022).

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NOVI ZAPIS O VRSTI *OPLEGNATHUS FASCIATUS* (TEMMINCK & SCHLEGEL, 1844), PACIFIŠKI VRSTI, V SREDOZEMLJU: NOVA NAJDBA IZ BENGAZIJA V LIBIJI

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POVZETEK

Avtorji poročajo o prvem pojavljanju cunami ribe, Oplegnathus fasciatus*, v libijskih vodah v južnem Sredozemskem morju. Ta vrsta domuje v severozahodnem in osrednjem vzhodnem Tihem oceanu, o njeni prisotnosti v Sredozemlju pa so poročali že v prejšnjih posameznih zapisih o pojavljanju. Primerek te vrste je bil ulovljen 3. februarja 2023 ob obali Bengazija na globini približno 12 m s triplastno stoječo mrežo. Za identifikacijo vrste so avtorji uporabili tako morfološke in meristične analize kot tudi genetsko potrditev s pomočjo mitohondrijskega gena COI. Avtorji nadalje razpravljajo o možnih poteh vnosa te vrste v južno Sredozemsko morje. Ključni prihodnji cilj je usmerjen v izkoriščanje potenciala ljubiteljske znanosti za krepitev ozaveščenosti javnosti in izboljšanje zmogljivosti za zgodnje odkrivanje tujerodnih vrst.*

Ključne besede: tujerodne vrste, mitohondrijski COI, Oplegnathidae, ladijski promet

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RAPID INCREASE IN RECORDS OF THE INVASIVE SILVER-CHEEKED TOADFISH *LAGOCEPHALUS SCELERATUS* (GMELIN, 1789) IN THE ADRIATIC SEA

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ABSTRACT

The silver-cheeked toadfish Lagocephalus sceleratus *(Gmelin, 1789) is a highly invasive Lessepsian migrant causing major ecological and socio-economic impacts in the Mediterranean Sea. Although the species was previously rare and sporadic in the Adriatic Sea, this study documents a sudden increase in its records between late March and early May 2026. Data were obtained from recreational and professional fisheries and validated through morphological identification and satellite-derived sea surface temperature (SST) data. Five new records were reported during this period, with four documented within less than two weeks along the eastern Adriatic and Albanian coasts, representing the highest number of records recorded over such a short interval in the region. SST values ranged from 14.69 °C to 15.68 °C. These findings indicate an increasingly regular presence, likely linked to sea warming.*

Key words: *Lagocephalus sceleratus*, Adriatic Sea, Lessepsian migration, invasive species, climate change, range expansion

RAPIDO AUMENTO DELLE SEGNALAZIONI DEL PESCE PALLA ARGENTEO INVASIVO *LAGOCEPHALUS SCELERATUS* (GMELIN, 1789) NEL MAR ADRIATICO

SINTESI

Il pesce palla argenteo, Lagocephalus sceleratus *(Gmelin, 1789), è un migrante lessepsiano altamente invasivo che provoca impatti ecologici e socioeconomici significativi nel Mediterraneo. Sebbene la specie fosse in precedenza rara e presente solo sporadicamente nell' Adriatico, lo studio documenta un improvviso aumento delle sue segnalazioni tra fine marzo e inizio maggio 2026. Durante questo periodo sono state registrate cinque nuove segnalazioni, di cui quattro documentate in meno di due settimane lungo le coste dell'Adriatico orientale e dell'Albania, rappresentando il più alto numero di osservazioni registrato in un intervallo di tempo così breve nella regione. I valori di SST variavano da 14,69 °C a 15,68 °C. Questi risultati indicano una presenza sempre più regolare della specie, probabilmente collegata al riscaldamento del mare.*

Parole chiave: *Lagocephalus sceleratus*, Adriatico, migrazione lessepsiana, specie invasiva, cambiamento climatico, espansione dell'areale

INTRODUCTION

Hundreds of marine species have entered the Mediterranean Sea from the Red Sea and the Indian Ocean through the Suez Canal, establishing populations primarily in its eastern basin and progressively spreading toward other regions. This phenomenon, known as Lessepsian migration, is now considered the largest marine biological invasion in the world. The influx of non-indigenous species, together with the introduction of warmer and more saline waters from the Red Sea – further amplified by ongoing climate change – is driving substantial alterations in the structure and composition of Mediterranean marine biodiversity. Increasing sea temperatures are creating more favourable conditions for thermophilic Lessepsian migrants, facilitating their establishment and expansion. The Adriatic Sea, as the northernmost and one of the coldest sub-basins of the Mediterranean, has historically acted as a barrier to the spread of such species. However, recent environmental changes, including rising temperature and salinity (Terzić *et al*., 2025), indicate that this barrier is weakening. Until the beginning of the 21st century, only eight Lessepsian fish species had been recorded in the Adriatic Sea since the 1800s (Dulčić *et al*., 2004), most of them along the eastern coast. Over the last two decades, however, this number has nearly doubled, with at least 15 species now reported, several of which show an increasing frequency of occurrence (Dulčić & Dragičević, 2023).

Among these, the silver-cheeked toadfish *Lagocephalus sceleratus* (Gmelin, 1789) is of particular concern, not only due to its potential impact on native biodiversity but also because of the risks it poses to human health. This invasive Lessepsian migrant is native to the tropical Indo-Pacific region. Following its entry into the Mediterranean via the Suez Canal, it was first recorded in 2003 off the southeastern Aegean coast of Turkey (Akyol *et al*., 2005). Since then, *L. sceleratus* has undergone rapid and continuous range expansion, colonising large parts of the eastern and central Mediterranean, reaching the Strait of Gibraltar, and extending into the Black Sea (Milazzo *et al*., 2012; Azzuro *et al*., 2020; Ulman *et al*., 2021). The species is a generalist carnivorous predator, feeding on crustaceans, fish, and cephalopods. Its maximum reported weight outside the Mediterranean is 7 kg (Smith & Heemstra, 1986), whereas in the Mediterranean, individuals weighing 8–9 kg have been documented (Ulman *et al*., 2022), with unconfirmed reports of specimens reaching up to 10–12 kg along the Turkish coast (Ulman *et al*., 2021).

The species is of particular concern due to its ecological and socio-economic impacts. Being a voracious predator with few natural enemies, particularly in the Mediterranean, it can disrupt and alter local food webs. Additionally, its strong dentition causes considerable damage to fisheries. It has already been observed that *L. sceleratus* causes substantial economic losses, particularly in the small-scale fishing sector, through depredation on fish entangled in fishing gear, as well as extensive damage to fishing equipment, for example by biting and severing parts of netting or hooks on longlines. These interactions result in increased labour and equipment costs for the fisheries sector, in addition to catch losses (Ünal & Bodur, 2017). Moreover, the presence of highly poisonous tetrodotoxin (TTX) in its tissues, including the muscles, skin, and specific organs, makes the fish highly toxic and posing a serious risk to human health if consumed. In fact, there have already been several reported cases of fatal poisoning (Ulman *et al*., 2021, 2022).

In the Adriatic Sea, *L. sceleratus* has historically been considered a rare and sporadic visitor. The first documented record dates back to October 2012, when a single female specimen was caught by beach seine near Jakljan Island in the southern Adriatic (Sulić Šprem *et al*., 2014). This was followed by a limited number of additional records between 2013 and 2014, when two specimens were reported from the central-eastern Adriatic (Dulčić *et al*., 2014). Another record of *L. sceleratus* was reported from the western Adriatic coast, Italy, in 2014 (Carbonara *et al*., 2017), and later from Albanian waters in 2019 (Kousteni *et al*., 2019). The most recent record, which also represents the northernmost occurrence in the Mediterranean, was reported in May 2024 from Medulin Bay in the northern Adriatic (Iveša *et al*., 2025).

Despite these observations, the species has appeared only intermittently over a period of more than a decade. The present study reports these new findings and discusses their implications in the context of ongoing environmental changes and potential shifts in species distribution patterns.

MATERIAL AND METHODS

Data on new occurrences of *Lagocephalus sceleratus* were collected opportunistically during March and in May 2026 through a combination of direct reports from recreational fishers and professional fishing activities. Each record included information on capture location, date, fishing gear used, and, where available, morphometric data (total length and weight). Species identification was performed based on external morphological characteristics following standard taxonomic descriptions (Smith & Heemstra, 1986), including body shape, coloration, and the distinctive silver lateral band.

Sea surface temperature (SST) data corresponding to the observation period were obtained from publicly available satellite datasets (Copernicus Marine Service), allowing for a comparison of thermal conditions across the recorded locations.

All records were georeferenced and mapped to assess their spatial distribution along the Adriatic coastline.

RESULTS AND DISCUSSION

In March 2026, four new records of *L. sceleratus* were documented within a period of less than two weeks, with an additional fifth record from 1 May, representing a notable increase compared to the previously sporadic occurrence pattern in the Adriatic Sea (Fig. 1).

The first specimen was recorded in the southern Adriatic. Shortly thereafter, a second individual was observed near Split in the central-eastern Adriatic. A third specimen was captured a few days later by a recreational angler in the nearby Makarska area at a depth of approximately 40 m (Fig. 2). The fourth record originated from the Karaburun Peninsula (Bay of Vlorë, Albania), where a specimen measuring 45 cm in total length and weighing approximately 1 kg was accidentally caught using a trammel net. The fifth record was also reported from the Bay of Vlorë on 1 May, where a recreational angler caught a specimen measuring 55 cm in length and weighing 2.65 kg. Sea surface temperatures during the observation period ranged from 14.69 °C in the central-eastern Adriatic, near the recording locations, to 15.68 °C in the southern Adriatic near the Bay of Vlorë.

These records span a broad latitudinal gradient along the eastern Adriatic coast and represent the highest number of observations reported within such a limited time interval in this region. The sudden increase in records of *L. sceleratus* in the Adriatic Sea sharply contrasts with the previous sporadic pattern observed between 2012 and 2024. The detection of five individuals within a short period of time, across a wide geographic area, may indicate a shift from occasional occurrence toward a more regular presence.

One possible explanation for this pattern is the ongoing warming of the Adriatic Sea, which is part of a broader and well-known trend affecting the Mediterranean basin. As a thermophilic species, *L. sceleratus* is likely to benefit from rising sea temperatures, which may facilitate both its survival during winter months and its northward expansion. Although the recorded sea surface temperatures during the 2026 study period have still been relatively moderate, they can nevertheless reflect increasingly favourable environmental conditions compared to previous decades, particularly during late winter and early spring, periods that were historically more limiting for such species.

Additionally, the clustering of records could be linked to increased detectability rather than a true population increase. Enhanced awareness among fishers and the growing use of digital communication platforms may contribute to improved reporting of rare or unusual species. Nevertheless, the spatial distribution and narrow temporal window of these observations suggest that ecological drivers are likely the primary cause of this pattern rather than reporting bias alone. The Adriatic Sea has traditionally been considered less susceptible to Lessepsian invasions compared to the eastern Mediterranean, primarily due to its lower temperatures and semi-enclosed nature. However, recent studies indicate that this barrier may be weakening. For instance, the rapid expansion of other thermophilic invasive species, such as the devil firefish, *Pterois miles* (Bennett, 1828), demonstrates that the Adriatic is becoming increasingly suitable for species of tropical origin (Bakiu *et al.*, 2024). The northernmost record of *L. sceleratus* from Medulin Bay (Iveša *et al.*, 2025), together with the present findings, further supports this trend and suggests a progressive northward shift in species distribution.

Fig. 1. Previous locations of *Lagocephalus sceleratus* ***records in the Adriatic Sea between 2012 and 2024 (•) and locations of records between late March and early May 2026 (★).***
Sl. 1. Lokacije predhodnih najdb vrste *Lagocephalus sceleratus* ***v Jadranskem morju med letoma 2012 in 2024 (•) in lokacije najdb med koncem marca in začetkom maja 2026 (★).***

L. sceleratus has been reported to be rapidly expanding across a variety of Mediterranean habitats, often becoming locally abundant in newly colonised areas (Ulman *et al.*, 2021, 2022). Previous predictive studies have already indicated that suitable habitats for this species are likely to increase in the Adriatic Sea under future climate scenarios. Using a modelling approach, D'Amen and Azzurro (2020) projected that, by 2050, most of the Adriatic Sea could become suitable for the species, with the possible exception of the northernmost areas, which currently face lower invasion risk due to less favourable environmental conditions. Similar conclusions were reached in a recent study based on species distribution models

Fig. 2. A specimen of *Lagocephalus sceleratus* ***caught on 22 March 2026 near Makarska.***
Sl. 2. Primerek vrste *Lagocephalus sceleratus****, ulovljen 22. marca 2026 v bližini Makarske.***

(SDMs) (Weterings *et al*., 2026), which also emphasised that completely halting the spread of *L. sceleratus* in the Mediterranean is no longer a realistic goal, given the species' established populations and rapid expansion. Instead, the authors advocate for adaptive management and mitigation strategies, including increased public awareness regarding the species' toxicity.

Given the well-documented ecological impacts of *L. sceleratus*, as well as its potential risks to fisheries and human health, the observed increase in records in the Adriatic Sea warrants particular attention. Continued and systematic monitoring is essential to determine whether this pattern reflects the early stages of population establishment or a temporary influx of individuals. In this context, the integration of citizen science data with validated scientific observations represents a valuable approach for improving early detection and tracking the spread of invasive species. Furthermore, targeted monitoring efforts, particularly in areas where repeated records are now emerging, could help clarify whether local reproduction is occurring, which would indicate a more advanced stage of establishment.

At present, it remains unclear whether *L. sceleratus* has established a self-sustaining population in the Adriatic Sea, as has already been documented for *Pterois miles*. However, the increasing frequency of records, including those reported in this study, suggests that such a scenario may become increasingly likely in the near future.

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HITRO NARAŠČANJE POJAVOV INVAZIVNE SREBRNOPROGE NAPIHOVALKE *LAGOCEPHALUS SCELERATUS* (GMELIN, 1789) V JADRANSKEM MORJU

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POVZETEK

Srebrnoproga napihovalka Lagocephalus sceleratus *(Gmelin, 1789) je močno invazivna lesepska selivka, ki povzroča velike ekološke in družbeno-ekonomske posledice v Sredozemskem morju. Ta vrsta je bila v Jadranskem morju prej redka in občasna, pričujoča raziskava pa ugotavlja nenaden porast najdb med koncem marca in začetkom maja 2026. Podatke sta avtorja pridobila iz ljubiteljskega in gospodarskega ribolova ter potrdila s pomočjo morfološke identifikacije in satelitskih podatkov o temperaturi morske gladine (SST). V tem obdobju je bilo zabeleženih pet novih najdb, od katerih so bile štiri dokumentirane v manj kot dveh tednih vzdolž vzhodne jadranske in albanske obale, kar predstavlja največje število zabeleženih pojavov v tako kratkem času na tem območju. Vrednosti SST so se gibale med 14,69 °C in 15,68 °C. Te ugotovitve so v nasprotju s sporadičnimi pojavljanji, zabeleženimi med letoma 2012 in 2024, ter nakazujejo premik k rednejši prisotnosti, kar je najverjetneje povezano z naraščanjem temperatur morja, ki ugodno vplivajo na toploljubne vrste.*

Ključne besede: *Lagocephalus sceleratus*, Jadransko morje, lesepska selitev, invazivna vrsta, podnebne spremembe, širjenje areala

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FURTHER MOLECULAR IDENTIFICATION CONFIRMS THE OCCURRENCE OF *LAGOCEPHALUS GUENTHERI* MIRANDA RIBEIRO, 1915 IN THE AEGEAN COASTAL WATERS OF GREECE

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ABSTRACT

The occurrence of the diamondback puffer Lagocephalus guentheri *Miranda Ribeiro, 1915 in the Greek waters of the Aegean Sea is herein confirmed through DNA barcoding based on a 608 bp fragment of the mitochondrial COI gene of a specimen collected on 14 September 2025 along the northwest coast of Rhodes Island, southeastern Aegean Sea, Greece. Morphological traits are evaluated alongside molecular data, with all nucleotide sequences used in the phylogenetic analysis consistently supporting the identification of* L. guentheri. *The present study aims to clarify the existence of this species in the region and to contribute additional reference sequences to public databases.*

Key words: Nucleotide sequence, genetic identification, non-indigenous fish, Tetraodontidae, Eastern Mediterranean

ULTERIORE IDENTIFICAZIONE MOLECOLARE CONFERMA LA PRESENZA DI *LAGOCEPHALUS GUENTHERI* MIRANDA RIBEIRO, 1915 NELLE ACQUE COSTIERE GRECHE DELL'EGEO

SINTESI

La presenza del pesce palla Lagocephalus guentheri *Miranda Ribeiro, 1915 nelle acque greche del mar Egeo viene confermata attraverso il DNA barcoding basato su 608 frammenti del gene mitocondriale COI di un esemplare raccolto il 14 Settembre 2025 nelle acque della costa nordoccidentale dell'isola di Rodi, mar Egeo sudorientale, Grecia. Le caratteristiche morfologiche vengono descritte mentre tutti i dati molecolari usati per l'analisi filogenetica confermano con certezza l'identificazione di* L. guentheri. *Lo studio ha lo scopo di chiarire l'esistenza della specie nella regione e di fornire ulteriori sequenze alle banche dati.*

Parole chiave: sequenze nucleotidiche, identificazione genetica, pesci non-indigeni, Tetraodontidae, Mediterraneo orientale

INTRODUCTION

Among the 10 Tetraodontidae species present in the Mediterranean, including the questionable *Lagocephalus spadiceus* (Richardson, 1845), seven occur with certainty in the Greek waters of the Aegean Sea, namely the native *Lagocephalus lagocephalus* (Linnaeus, 1758), the non-indigenous from the Indo-Pacific/Red Sea (Lessepsian migrants) *Lagocephalus guentheri* Miranda Ribeiro, 1915, *Lagocephalus suezensis* Clark & Gohar, 1953, *Tylerius spinosissimus* (Regan, 1908), *Lagocephalus sceleratus* (Gmelin, 1789) and *Torquigener hypselogeneion* (Bleeker, 1852), and finally the range-expanding from the Atlantic *Sphoeroides pachygaster* (Müller & Troschel, 1848) (Corsini *et al.*, 2005; Papaconstantinou, 2014; Vella *et al.*, 2017; Giusti *et al.*, 2019; Kovačić *et al.*, 2021; Deidun *et al.*, 2024).

With the exception of the rarely encountered and small-sized *T. spinosissimus*, the other four non-indigenous tetraodontid species recorded in the Greek Aegean Sea have colonized the eastern Mediterranean coastal waters to varying degrees of population density, depending on the species. Some have expanded as far as the central Mediterranean, while the highly invasive, highly toxic, and large-sized *L. sceleratus* has impressively crossed the Sicily Channel westward, reaching the Strait of Gibraltar within just two decades of its first record in 2003 (Akyol *et al*., 2005; Golani, 2021).

Among the above non-indigenous tetraodontids, *L. guentheri*, *L. suezensis* and *T. spinosissimus* are considered established in the Greek Aegean waters, while *L. sceleratus* and *T. hypselogeneion* are considered invasive (Zenetos *et al.*, 2024).

The Lessepsian migrant *L. guentheri* is native to the Red Sea and the Indo-West Pacific Ocean, from South Africa, Madagascar and Persian Gulf east to India, Indonesia northwestern Australia and the South China Sea and as north as southern Japan (Golani & Fricke, 2018; Froese & Pauly, 2025).

In the Greek coastal waters, *L. guentheri* was first recorded from Samos, North Aegean Sea as *Tetrodon spadiceus* Richardson, 1845, in 1952 (Ananiadis, 1952). Subsequent records came from Kos Island in 2007 (specimen preserved under the number HSR92 at the collection of the Hydrobiological Station of Rhodes, Hellenic Centre for Marine Research, HSR/HCMR), from Rhodes Island in 2008 (both reported as *L. spadiceus*; Corsini-Foka, 2010), from off Paralia Dikellon, Evros, North Aegean in 2007 (Evangelopoulos *et al.*, 2024; Zenetos *et al.*, 2024), and from off Pachi, Megara Gulf, Attica, western Aegean in 2017 (Kleitou *et al.*, 2018). Following the revision of the taxonomic status and distribution of *L. guentheri* by Matsuura *et al.* (2011), the earlier records of *L. spadiceus* previously reported in the Greek coastal waters were re-evaluated and subsequently considered misidentifications of *L. guentheri* (Corsini-Foka *et al.*, 2015; Zenetos *et al.*, 2017, 2018, 2024). Consistently, a specimen collected in 2016 from Crete and genetically identified as *L. spadiceus* was later reassigned to *L. guentheri* (Giusti *et al.*, 2019).

Records of the species throughout the Mediterranean, including the first from Israel in 1949, come from Egypt, Libya, Lebanon, Syria, Cyprus, Mediterranean and Aegean waters of Turkey and Malta; as *Tetrodon spadiceus* Richardson, 1845 (Kosswig, 1950; Ben-Tuvia, 1953), as *L. spadiceus* (Ali, 2018), as *Sphaeroides spadiceus* (Richardson, 1845) (Por, 1978); as *L. guentheri* (Iglésias & Frotté, 2015; Akyol & Aydın, 2016; Farrag *et al.*, 2016; Golani & Fricke, 2018; Bariche & Fricke, 2020; Deidun *et al.*, 2024; Zenetos *et al.*, 2024).

Due to the extreme similarities and only slight differences between *L. guentheri* and *L. spadiceus*, the significance and high importance of combining the proper distinguishing morphological characters (Matsuura *et al.*, 2011; Psomadakis *et al.*, 2015) with molecular data has been stated and thoroughly discussed in recent scientific literature (Turan *et al.*, 2017; Vella *et al.*, 2017; Giusti *et al.*, 2019; Deidun *et al.*, 2024).

Proper identification of *Lagocephalus* species occurring in the study area is fundamental to determining the current population status of *L. guentheri*, thereby, this study provides baseline data necessary to evaluate its potential invasiveness and related ecological and socio-economic impacts.

MATERIAL AND METHODS

On 14 September 2025, during a fisheries survey, an individual of Tetraodontidae was acquired by the first author from a fisher at the dock of Kremasti Village, located at the northwest coast of Rhodes Island (36.41867°N, 28.11655°E). Recreational rod-and-line angling was being performed by the fisher from the dock, at an approximate depth of less than 3 m using handmade bread dough as bait. The individual had been left on the dock, exposed to the sun and heat for approximately 1-2 hours. It was then transported to the facilities of the Hydrobiological Station of Rhodes (HSR) for meristic characters and morphometric measurements and identification based on key features described by Matsuura *et al.* (2011), Matsuura (2022) and Psomadakis *et al.* (2015) and other relevant publications that focus on the morphological differences of the two most likely species our individual resembled, namely *L. guentheri* and *L. spadiceus* (Giusti *et al.*, 2019; Deidun *et al.*, 2024). After preservation in the fridge at 4°C, the following morning photographs were taken with a Nikon AW111 camera and tissue sampling for DNA analysis was performed. The specimen (Fig. 1) and the tissue sample were fixed in 70% and absolute ethanol respectively, and the former was registered in the HSR collection with a Voucher number HSR.VOUCHER.579.

Genetic identification of the specimen was carried out using DNA barcoding. Genomic DNA was isolated from the sampled muscle tissue using the QIAamp DNA Mini Kit (Qiagen, Hilden, Germany), according to the manufacturer's protocol. A partial region of the mitochondrial cytochrome c oxidase I (COI) gene was amplified with the primers FISHCOILBC_ts and FISHCOIHBC_ts (Handy *et al.*, 2011). PCR amplifications were performed in a 30 µL reaction containing 1× PCR buffer, 2.5 mM MgCl2, 0.2 mM dNTPs, 0.4 µM of each primer, 1 U Taq DNA polymerase, and 50–100 ng of template DNA. Thermal cycling consisted of an initial denaturation at 94 °C for 3 min, followed by 35 cycles of 95 °C for 40 s, 49 °C for 40 s, and 72 °C for 40 s, with a final extension at 72 °C for 5 min. PCR products were examined on 2% agarose gels and subsequently sequenced by GENEWIZ Germany GmbH (part of Azenta Life Sciences). The sequence was deposited to BOLD Systems database (Sample ID: HSR.DNA.041).

A total of 12 nucleotide sequences were included in the phylogenetic analysis; KY130423, KR861535, KY176508, PP338021, KM538365, KF442241, HQ149858, LC155438, HQ167726, EU595160 and KP266858. Sequences were aligned and trimmed to a final length of 590 bp. Phylogenetic relationships were inferred using the Maximum Likelihood (ML) method. The best-fit nucleotide substitution model was selected based on model testing in MEGA (Tamura *et al.*, 2023), using information criteria. The Kimura 2-parameter (K2) model was identified as the optimal model, with Bayesian Information Criterion (BIC) = 2645.47, Akaike Information Criterion (AIC) = 2494.58, and log-likelihood (lnL) = −1225.22. This model was subsequently applied for ML tree construction. Node support was assessed using non-parametric bootstrap analysis with 1000 replicates. Bootstrap values were mapped onto the consensus ML tree to evaluate the robustness of inferred clades. The resulting phylogenetic tree was visualized and edited for presentation in FigTree (Rambaut, 2018).

RESULTS AND DISCUSSION

The meristic characters of the specimen under study were D 12, A 11, P 16 and C 13 all included within the range of the values D 12 - 14, A 11 - 12, P 16 – 19, C 13 – 17, cumulatively provided in published literature (Matsuura *et al.*, 2011; Psomadakis *et al.*, 2015; Akyol & Aydın, 2016; Erguden *et al.*, 2017; Kiparissis *et al.*, 2018; Golani *et al.*, 2021; Deidun *et al.*, 2024). Proportions of measurements expressed as % of standard length (Tab. 1) were compared and agreed with published literature (Appendices 1 and 2).

In agreement with Fig. 2 in Matsuura *et al.* (2011) and Psomadakis *et al.* (2015), a rhomboidal spinule patch on the back extending posteriorly to the region dorsal to the posterior part of the pectoral fin but not extending to dorsal fin origin, was clearly observed on our specimen. The length from snout to the posteriormost spinule was 53.16 mm whereas the distance from snout to dorsal fin origin was 80.05 mm (Tab. 1).

As far as the colour is concerned, while fresh, the specimen had a clear slightly lunate caudal fin with white upper and lower tips and traces of a medial posterior projection, as described in Matsuura *et al.* (2011), Matsuura (2022) and Psomadakis *et al.* (2015). Nevertheless, a slight differentiation of the caudal fin was apparent. The dorsal 2/3 of the caudal fin was brownish yellow while the ventral 1/3, apart from

Fig. 1: *Lagocephalus guentheri* ***Miranda Ribeiro, 1915, from the northwestern waters of Rhodes, southeastern Aegean Sea, Greece. Scale bar: 1 cm.***
Sl. 1: *Lagocephalus guentheri* ***Miranda Ribeiro, 1915, iz severozahodnih voda Rodosa, jugovzhodno Egejsko morje, Grčija. Merilo: 1 cm.***

Tab. 1: Morphometrics of* Lagocephalus guentheri *specimen from northwest coast of Rhodes Island, southeastern Aegean Sea, Greece. SL = standard length.
Tab. 1:Morfometrične meritve primerka vrste* Lagocephalus guentheri *s severozahodne obale otoka Rodos, jugovzhodno Egejsko morje, Grčija. SL = standardna dolžina.

Measurements	**mm**	**SL %**
Total length	143.2	
Standard length	134.5	
Head length	41.43	30.80
Snout length	19.54	14.53
Snout to dorsal-fin origin	80.05	59.52
Snout to anal-fin origin	85.57	63.62
Body depth at pectoral-fin base	38.11	28.33
Body depth at anal-fin origin	27.63	20.54
Depth of the caudal peduncle	8.08	6.01
Length of caudal peduncle	31.31	23.28
Gill opening length	10.62	7.90
Eye diameter	10.94	8.13
Bony interorbital width	15.51	11.53
Snout to nasal organ	13.91	10.34
Nose to eye	6.20	4.61
Length of dorsal-fin base	13.23	9.84
Length of anal-fin base	10.60	7.88
Longest dorsal-fin ray	23.25	17.29
Longest anal-fin ray	21.41	15.92
Longest pectoral-fin ray	21.09	15.68
Caudal-fin length	32.36	24.06

the white tip, had a blackish/white hue throughout its length (Fig.1), characters that could be attributed to *L. spadiceus* according to Matsuura *et al.* (2011), the illustrations in Psomadakis *et al.* (2015) and as pointed out in Giusti *et al.* (2019).

However, the observed differentiations, most likely a discoloration, may have resulted from the prolonged exposure of our specimen to the sun and atmospheric conditions leading to a loss of freshness, or from color variation within the species. The latter represents a well-documented theme in fish evolution and ecology, with numerous studies reporting geographically structured, population-level color differentiation. Such variation is often associated with differences in habitat and light environment, as well as with sexual selection, predation pressure, or genetic drift, *e.g.* in *Coris julis* (Linnaeus, 1758) (Fruciano *et al.*, 2011) and pufferfishes (Yamanoue *et al.*, 2009).

Overall morphological examination revealed that the specimen most probably belonged to the species *L. guentheri*. Since issues with the identification of *L. spadiceus* and *L. guentheri* in the Mediterranean have previously been highlighted (Turan et al., 2017; Vella *et al.*, 2017; Deidun *et al.*, 2024), we considered it necessary to confirm the identity of the individual through DNA barcoding. Molecular analysis, indeed, provided an unequivocal validation, assigning the specimen to the species *L. guentheri* (Fig. 2).

The Maximum Likelihood phylogenetic analysis based on 590 bp nucleotide sequences resolved the relationships among the analyzed Lagocephalus taxa with strong statistical support (Fig. 2). The resulting tree clearly separated the sequences into three well-supported clades corresponding to *L. guentheri*, *L. spadiceus* and *Lagocephalus cheesmanii* (Clarke, 1897).

All sequences identified as *L. guentheri*, following the corrections by Giusti *et al.* (2019) for sequences KY130423, KR861535 and KM538365, clustered together in a monophyletic clade (haplogroup α; Giusti *et al.*, 2019) with high bootstrap support (100%). This clade included reference sequences from Greece, Lebanon, Turkey, Malta, Israel, India, and Iran, as well as our specimen, which grouped within the *L. guentheri* cluster, confirming its species-level identification. A second strongly supported clade (bootstrap value = 100%) corresponded to *L. spadiceus* (haplogroup β; Giusti *et al.*, 2019) and comprised sequences originating from Japan, Turkey, and China.

An earlier DNA confirmation of *L. guentheri* in the under-study area (SE Aegean Sea), could have been possible based on the archived specimen HSR92 mentioned above (as *L. spadiceus*; Corsini-Foka, 2010). However, the latter, although later morphologically identified as *L. guentheri* following Matsuura *et al.* (2011), was no further involved in the present study as it was preserved for many years in formaldehyde, a substance not suitable for prolonged preservation prior to DNA analysis.

The present study provides unequivocal confirmation of the occurrence of *L. guentheri* in the Aegean Sea coasts of Greece through the combined application of detailed morphological examination and mitochondrial COI barcoding. Although minor colour-pattern deviations were observed, the specimen's meristic and morphometric characters were consistent with the diagnostic features of *L. guentheri*, while molecular analysis yielded clear phylogenetic placement within the species. These findings further corroborate previous evidence that historical Mediterranean records of *L. spadiceus* largely represent misidentifications of *L. guentheri*, underscoring the persistent taxonomic challenges posed by the close resemblance of these taxa. By contributing a vouchered specimen and a validated DNA sequences to public databases,

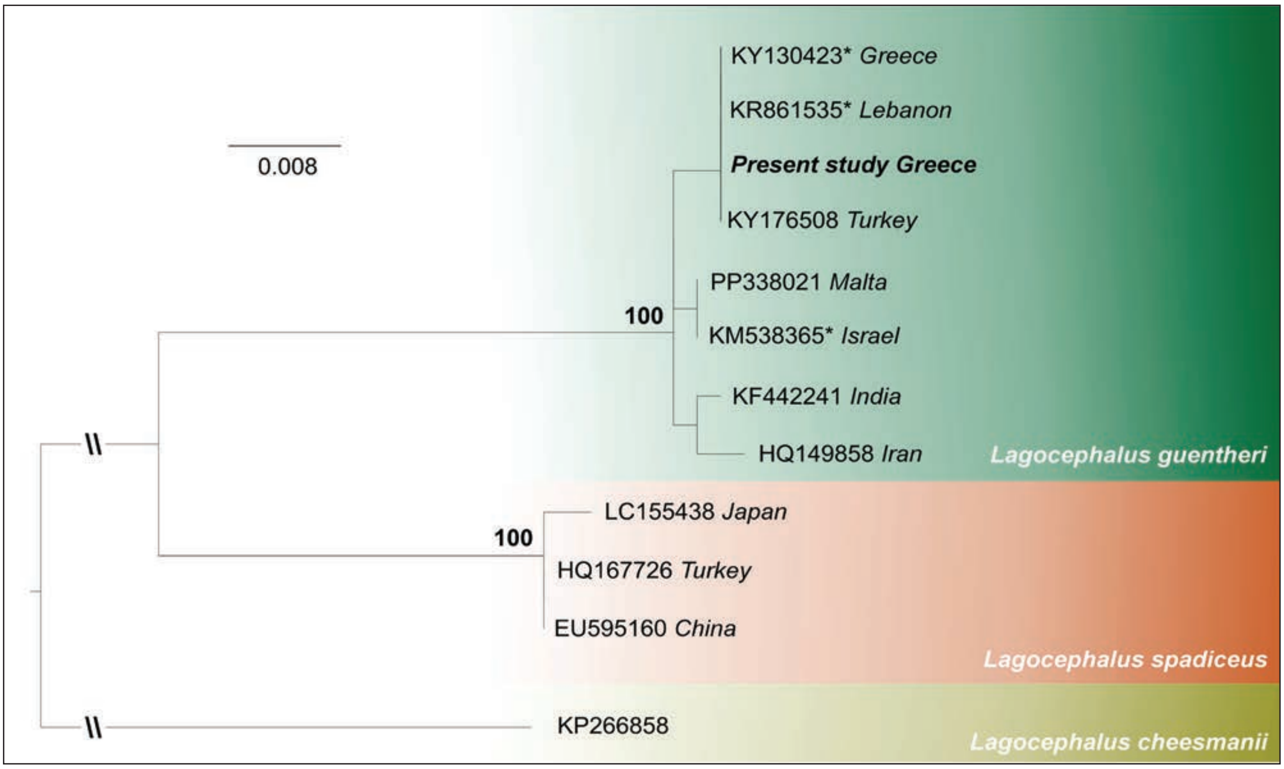

Fig. 2. Maximum-likelihood phylogenetic tree based on a 590 bp fragment of mitochondrial COI gene of* Lagocephalus *species. The analyzed specimen (in bold) clusters within the* Lagocephalus guentheri *clade, together with reference sequences from the Mediterranean and Indo-Pacific regions.* Lagocephalus spadiceus *and* L. cheesmanii *form well-supported, distinct clades. Bootstrap support values are shown at the nodes. Scale bar indicates genetic distance (substitutions per site). Asterisks refer to originally misidentified specimens.

Sl. 2: Najbolj verjetno filogenetsko drevo, ki temelji na 590 bp dolgem fragmentu mitohondrijskega gena COI vrst iz rodu* Lagocephalus*. Analizirani primerki (v krepkem tisku) se združujejo znotraj klada* Lagocephalus guentheri*, skupaj z referenčnimi zaporedji iz sredozemske in indo-pacifiške regije.* Lagocephalus spadiceus *in* L. cheesmanii *tvorita dobro podprte, ločene klade. Vrednosti podpore bootstrap so prikazane na vozliščih. Merilna vrstica označuje genetsko razdaljo (zamenjave na mesto). Zvezdice se nanašajo na prvotno napačno identificirane primerke.

this study enhances the reliability of reference material for the genus and supports recent assessments documenting the ongoing westward expansion of *L. guentheri* in the Mediterranean. The results reinforce the necessity of integrating morphological criteria with molecular tools in the accurate identification of non-indigenous pufferfishes, a prerequisite for reliable biogeographic assessments, biodiversity monitoring, and effective management of toxic species in Mediterranean waters.

CONCLUSIONS

The present study confirms the occurrence of *Lagocephalus guentheri* in the Aegean Sea coasts of Greece through the combined use of morphological examination and mitochondrial COI region. Although slight colour-pattern deviations were observed, the meristic and morphometric characters of the examined specimen were consistent with published diagnostic features of the species, while molecular analysis provided unequivocal species-level validation. These findings further support the view that previous records of *L. spadiceus* from Greek waters largely refer to misidentified *L. guentheri*. By contributing a vouchered specimen and a validated DNA sequences to public databases, this study improves the reliability of reference material for *Lagocephalus* in the Mediterranean and highlights the importance of integrating morphological and molecular approaches for the accurate identification and monitoring of non-indigenous pufferfishes.

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NADALJNJA MOLEKULARNA IDENTIFIKACIJA POTRJUJE PRISOTNOST VRSTE *LAGOCEPHALUS GUENTHERI* MIRANDA RIBEIRO, 1915 V EGEJSKIH OBALNIH VODAH GRČIJE

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POVZETEK

Avtorji potrjujejo pojav zlate napihovalke Lagocephalus guentheri *Miranda Ribeiro, 1915 v grških vodah Egejskega morja z DNK barkodiranjem na podlagi 608 bp dolgega fragmenta mitohondrijskega gena COI primerka, odvzetega 14. septembra 2025 ob severozahodni obali otoka Rodos v jugovzhodnem Egejskem morju v Grčiji. Morfološke lastnosti so ocenjene skupaj z molekularnimi podatki, pri čemer vsa nukleotidna zaporedja, uporabljena v filogenetski analizi, dosledno podpirajo identifikacijo* L. guentheri. *Namen pričujoče raziskave je potrditi pojavljanje te vrste v regiji in prispevati dodatne referenčne sekvence k javnim podatkovnim bazam.*

Ključne besede: nukleotidne sekvence, genetska identifikacija, tujerodne ribe, Tetraodontidae, vzhodno Sredozemlje

Appendix 1: Published morphometrics of *Lagocephalus guentheri* **holotype and specimens from the Mediterranean and the Red Sea.**
Priloga 1: Objavljene morfometrične značilnosti holotipa *Lagocephalus guentheri* **in osebkov iz Sredozemlja in Rdečega morja.**

Reference	**Ananiadis (1952)**		**Matsuura *et al*. (2011) Holotype**		**Matsuura *et al*. (2011)**		**Akyol & Aydın (2016)**		**Ergüden *et al*. (2017)**		**Vella *et al*. (2017)**		**Kiparissis *et al*. (2018)**		**Kleitou *et al*. (2018)**		**Deidun *et al*. (2024)**		**Present Study**	
Location	**NW Samos Isl., south Aegean Sea**		**Brazil**		**Red Sea**		**Çandarlı Bay, Turkey**		**Iskenderun Bay, Turkey**		**NE Mediterranean**		**South Crete**		**off Pachi, Attiki, central Aegean Sea**		**Birzebbuga, Marsaxlokk Bay, Island of Malta**		**Kremasti, Rhodes Island, southeastern Aegean sea**	
Year of record	**1952**		**1848**		**1972, 2009**		**2015**		**2017**		**<2017**		**2016**		**2017**		**2023**		**2025**	
Measurements	**mm**	**SL%**	**mm**	**SL%**	**mm**	**SL%**	**mm**	**SL%**	**mm**	**SL%**	**mm**	**SL%**	**mm**	**SL%**	**mm**	**SL%**	**mm**	**SL%**	**mm**	**SL%**
Total length	185						134		337		167-194		202		239		270		143.2	
Standard length (SL)	155		175		117-183		114		289		135-159		172		206		223		134.5	
Head length	46.02	29.69		34.5		30.5–32.6	33	28.9	79	27.3	48.8-55.6		51.2	29.76	64	31.07	70	31.39	41.43	30.80
Snout length (pre-orbital length)				17.1		15.4–16.6	14	12.3	17	5.88	17.1-20.7		22.6	13.14			29.7	13.32	19.54	14.53
Snout to dorsal fin origin (pre-dorsal fin length)				65.4		63.0–67.5	71	62.3	177	61.2	96.3-107.4		109	63.60			145	65.02	80.05	59.52
Snout to anal fin origin (pre-anal fin length)				69.4		64.8–66.7	73	64.0	176	60.9	93.7-105.9		112	65.23	115	55.82	148	66.37	85.57	63.62
Body depth at pectoral fin base				15.9		17.6–20.1											65	29.15	38.11	28.33
Body depth at anal fin origin				19.7		18.5–20.3											49	21.97	27.63	20.54
Depth of the caudal peduncle (minimum body depth)				5.7		5.4–6.2			19	6.6	8.0-9.3		9.5	5.52			12.9	5.75	8.08	6.00
Length of caudal peduncle (from end of anal fin) (end of anal base to end of SL)				24.6		25.8–26.8							47.4	27.55			58	26.01	31.31	23.28
Gill opening length				7.9		7.8–10.7											21.4	9.60	10.62	7.89
Eye diameter (eye width)	13.78	8.89		9.3		8.1–9.5	10	8.77	18	6.23	13.0-15.2		11.2	6.51			16	7.17	10.94	8.13
Bony interorbital width (interorbital distance/space)				11.5		10.8–13.5			42	14.5			26.1	15.17			29	13	15.51	11.53
Snout to nasal organ				10.9		9.8–11.3											23.1	10.36	13.91	10.34
Nose to eye				4.9		4.4–5.2											12.6	5.65	6.2	4.61
Length of dorsal fin base				10.5		10.4–11.1							18.1	10.52			20.6	9.24	13.23	9.84
Length of anal fin base (Anal Fin Base Length)				7.4		9.2–10.7							13.3	7.73			19.1	8.56	10.6	7.88
Longest dorsal fin ray				19.0		16.1–19.3			45	15.6							36.5	16.37	23.25	17.29
Longest anal ray (Anal Fin Length)				17.3		16.5–19.0			39	13.5			29.2	16.98			42.1	18.88	21.41	15.92
Longest pectoral ray (Pectoral Fin Length - from dorsal insertion point to end of longest ray)				15.6		16.8–18.5			41	14.2			29.3	17.03			38	17.04	21.09	15.68
Caudal fin length				22.9		21.6–24.8											45	20.18	32.36	24.06

Appendix 2: Published meristics of *Lagocephalus guentheri* ***holotype and specimens from the Mediterranean and the Red Sea.***
Priloga 2: Objavljene meristike holotipa *Lagocephalus guentheri* ***in osebkov iz Sredozemlja in Rdečega morja.***

Meristic parameters **Reference**	**Dorsal Fin rays**	**Anal Fin rays**	**Pectoral Fin rays**	**Caudal Fin rays**
Ananiadis (1952)	12	11		
Matsuura *et al.* (2011) Holotype	14	12	19	
Matsuura *et al.* (2011) Red Sea Specimens	12 to 13	11	16 to 17	
Matsuura *et al.* (2011)	12 to 14	11 to 12	16 to 19	
Psomadakis *et al.* (2015)	12 to 14	11 to 12		
Akyol & Aydın (2016)	12	11	16	
Ergüden *et al.* (2017)	13	11	19	17
Kiparissis *et al.* (2018)	13	11	16	13
Deidun *et al.* (2024)	12	11	17	
Present Study	12	11	16	13
Range	12 to 14	11 to 12	16 to 19	13 to 17

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LENGTH–WEIGHT AND LENGTH–LENGTH RELATIONSHIPS, AND CONDITION FACTOR OF *AMBASSIS DUSSUMIERI* CUVIER, 1828, IN THE NORTHEASTERN MEDITERRANEAN, TÜRKIYE

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ABSTRACT

This study provides the first data on the length–weight relationship (LWR), length–length relationship (LLR), and condition factor (K) *of the Malabar glassy perchlet,* Ambassis dussumieri, *in the northeastern Mediterranean (Tuzla coast, Türkiye). A total of 132 specimens (68 males and 64 females) were examined. The specimens ranged from 4.5 to 8.9 cm in total length (TL), 3.7 to 7.7 cm in fork length (FL), 3.4 to 6.9 cm in standard length (SL) for both sexes. The calculated* b *values indicated positive allometric growth for the overall population (t-test,* $p < 0.05$*). The length–length relationships among the three length measurements (TL, FL, and SL) were highly correlated (*$r^2 > 0.970$*). The mean condition factor* (K) *was calculated as 0.812 ± 0.074 for both sexes, with no significant difference between females and males. These results will be useful for studies on the biology of non-indigenous fish species.*

Key words: The Malabar glassy perchlet, biological parameters, Levantine Sea, Türkiye

RELAZIONI LUNGHEZZA–PESO E LUNGHEZZA–LUNGHEZZA, E FATTORE DI CONDIZIONE DI *AMBASSIS DUSSUMIERI* CUVIER, 1828, NEL MEDITERRANEO NORD-ORIENTALE, TURCHIA

SINTESI

Lo studio fornisce i primi dati sulla relazione lunghezza–peso (LWR), sulla relazione lunghezza–lunghezza (LLR) e sul fattore di condizione (K) del pesce vetro di Dussumier, Ambassis dussumieri*, nel Mediterraneo nord-orientale (costa di Tuzla, Turchia). È stato esaminato un totale di 132 esemplari (68 maschi e 64 femmine). Gli esemplari presentavano una lunghezza totale (TL) compresa tra 4,5 e 8,9 cm, una lunghezza alla forcella (FL) tra 3,7 e 7,7 cm e una lunghezza standard (SL) tra 3,4 e 6,9 cm per entrambi i sessi. I valori di b calcolati hanno indicato una crescita allometrica positiva per l'intera popolazione (t-test,* $p < 0,05$*). Le relazioni lunghezza–lunghezza tra le tre misure di lunghezza (TL, FL e SL) hanno mostrato un'elevata correlazione (*$r^2 > 0,970$*). Il fattore di condizione medio (K) è stato calcolato pari a 0,812 ± 0,074 per entrambi i sessi, senza differenze significative tra femmine e maschi. Questi risultati saranno utili per studi sulla biologia delle specie ittiche non indigene.*

Parole chiave: pesce vetro di Dussumier, parametri biologici, Mare del Levante, Turchia

INTRODUCTION

The Malabar glassy perchlet, *Ambassis dussumieri* Cuvier, 1828, is widely distributed in the Mediterranean Sea (Stern *et al.*, 2022) and throughout the Indo-West Pacific, from Algoa Bay in South Africa to the Red Sea and Seychelles, and eastwards to India, Australasia, the Philippines, and China (Anderson & Heemstra, 2003).

Ambassis dussumieri inhabits marine, estuarine, and riverine environments (Froese & Pauly, 2026). In the Mediterranean, the species was first recorded in the eastern basin, on the Israeli coast, by Stern *et al.* (2022) and subsequently reported by Çevik & Ergüden (2026) from Turkish marine waters in the northeastern Mediterranean. The pathway by which it entered the Mediterranean Sea remains uncertain, although Stern *et al.* (2022) suggested that the species likely migrated from the Red Sea to the Israeli coast via the Suez Canal.

The length–weight relationship (LWR) is an important tool in fish biology, ecology, and fisheries assessment, providing valuable information for stock assessment studies (Moutopoulos & Stergiou, 2002; Gonzalez Acosta *et al.,* 2004), particularly for converting length observations into weight estimates and assessing biomass (Gonzalez Acosta *et al.,* 2004).

The length–length relationship (LLR) is useful for standardising length types when summarising data and is also effective for comparative growth studies (Froese, 2006; Moutopoulos & Stergiou, 2002; Bakhshalizadeh *et al.,* 2025). Understanding relationships among total length, fork length, and standard length allows for the estimation of species distribution, assessment of population condition, and morphological comparisons. All these data contribute to informed decision-making and effective conservation strategies (Froese, 2006).

The present study aimed to investigate the length–frequency distribution, length–weight relationship (LWR), length–length relationship (LLR), and Fulton's condition factor (*K*) of the non-indigenous fish species of Malabar glassy perchlet *Ambassis dussumieri* in the northeastern Mediterranean Sea, Türkiye.

MATERIAL AND METHODS

A total of 132 specimens of *A. dussumieri* were collected in October, November, and December 2025 from the Kara Göçer Drainage Canal, Tuzla coast (Karataş, Adana), using a cast net (Fig. 1). Sampling was conducted approximately 400–500 m upstream from the canal mouth at a depth of

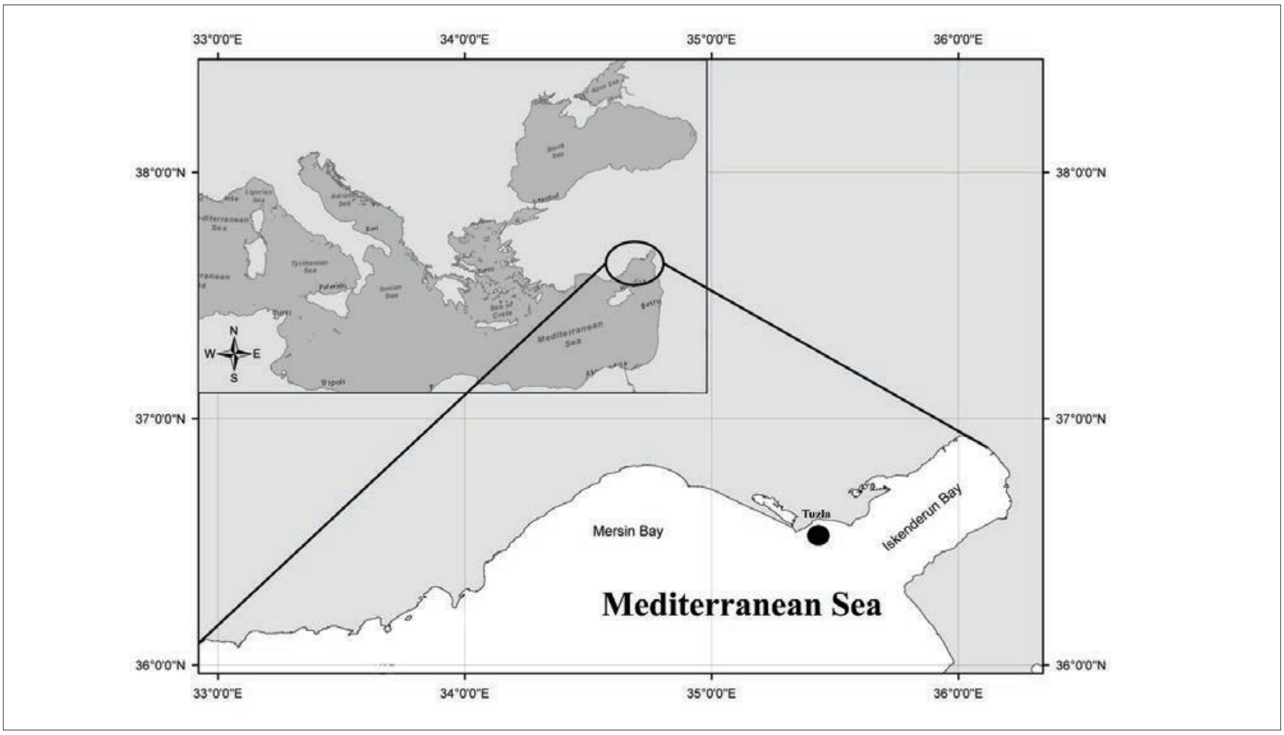

Fig. 1: Map showing the capture locality (•) of *Ambassis dussumieri* ***in the northeastern Mediterranean (Tuzla, Türkiye).***
Sl. 1: Zemljevid obravnavanga območja z lokaliteto ulova primerkov vrste *Ambassis dussumieri* ***v severovzhodnem Sredozemlju (Tuzla, Turčija).***

Tab. 1: Descriptive statistics and estimated parameters of the length–weight relationships of *Ambassis dussumieri* ***from the northeastern Mediterranean, Türkiye. a: = intercept, b: = slope, SE.: = Standard error, C.I: = Confidence interval, r2: = Coefficient of determination, GT: = Growth type.***

Tab. 1: Opisna statistika in ocenjeni parametri dolžinsko-masnih odnosov za vrsto *Ambassis dussumieri* ***iz severovzhodnega Sredozemlja, Turčija. a: = začetni koeficient (odsek), b: = naklon, SE.: = standardna napaka, C.I: = interval zaupanja, r2: = koeficient determinacije, GT: = tip rasti.***

Sample	**No. of indivi-duals**	**Total Length, TL (cm)**	**Weight, W (g)**	**Parameters of the relationship**					
Ambassis dussumieri		L_{min}-L_{max} (mean ±SD)	W_{min}-W_{max} (mean ±SD)	a	b	SE(b)	95% CI of b	r^2	GT
Female	64	4.50–8.60 (6.86±0.949)	0.75–6.51 (2.83±1.348)	0.0036	3.417	0.068	3.282–3.553	0.976	A+
Male	68	4.50–8.90 (6.93±1.127)	0.72–6.99 (2.99±1.467)	0.0058	3.175	0.058	3.060–3.292	0.978	A+
Combined	132	4.50–8.90 (6.90±1.040)	0.72–6.99 (2.90±1.382)	0.0050	3.253	0.044	3.167–3.340	0.976	A+

about 1.5 m. After collection, the specimens were transported in a small iced Styrofoam box to the Basic Sciences Laboratory at the Faculty of Fisheries Science, Çukurova University.

Species identification was carried out based on the diagnostic criteria provided by Maugé (1986) and Anderson and Heemstra (2003). For each fish specimen, total length (TL), fork length (FL), and standard length (SL) were measured to the nearest 0.1 cm, and total weight (TW) was recorded to the nearest 0.01 g.

The sex was determined by macroscopic observation of the gonads in all individuals. Specimens of the Malabar glassy perchlet were grouped into size classes, and percentage frequency and TL were used to construct the length–frequency distribution. The sex ratio (males:females) was calculated and significant deviations from the expected ratio (1:1) were tested using the χ^2 test (Zar, 1996).

The functional relationship between length and weight of the specimens was fitted to the equation $W = aL^b$, where W is total weight (g), L is length (cm), and a and b are parameters to be estimated, with b representing the coefficient of allometry (Ricker, 1975). The parameters a and b were estimated using the least-squares regression on log-transformed length and weight values (Le Cren, 1951), according to the linearized form $\log W = \log a + b \log L$ (Sokal & Rohlf, 1987).

The b value is useful in describing fish growth type and associated changes in body shape under specific environmental conditions. When $b = 3$, growth is isometric; values of $b < 3$ indicate negative allometric growth, whereas values of $b > 3$ indicate positive allometric growth (Ricker, 1975; Sparre & Venema, 1992; Avsar, 2016). Significant deviations of the estimated b value from the isometric value ($b = 3.0$) were tested using a t-test.

Fulton's condition factor was calculated from weight (g) and length (cm) and used to estimate changes in nutritional condition. The formula used was $K = 100 \times W / L^3$, where K is the condition factor, W is body weight, and L is total length (Le Cren, 1951; Pauly, 1980). Data were analysed using SPSS v22.0. All statistical tests were considered significant at the 0.05 level ($p < 0.05$).

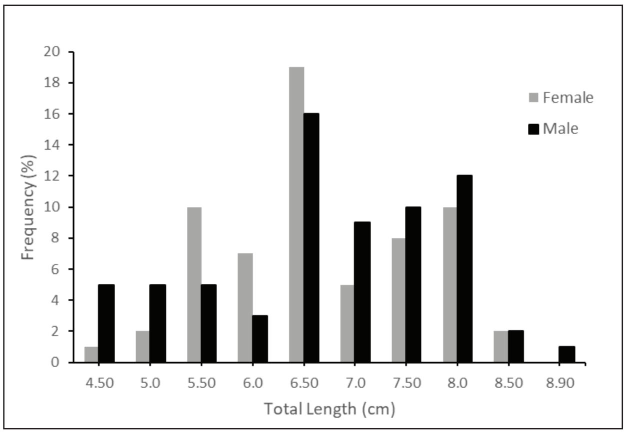

Fig. 2: Total length frequencies of female and male *Ambassis dussumieri* ***from the northeastern Mediterranean coast of Türkiye.***

Sl. 2: Frekvenčna porazdelitev celotne dolžine samic in samcev vrste *Ambassis dussumieri* ***s severovzhodne sredozemske obale Turčije.***

RESULTS AND DISCUSSION

A total of 132 specimens were examined. The specimens ranged from 4.5 to 8.9 cm in total length (TL), 3.7 to 7.7 cm in fork length (FL), 3.4 to 6.9 cm in standard length (SL), and 0.72 to 6.99 g in total weight (TW) for the two sexes combined (Tab. 1). The maximum total length recorded during the study period was 8.9 cm. In males, TL ranged from 4.5 to 8.9 cm, and TW from 0.72 to 6.99 g, while in females, TL ranged from 4.5 to 8.6 cm and TW from 0.75 to 6.51 g.

The results show that the studied population consisted of 51.52% males (n=68) and 48.48% females (n=64), with maximum length and weight values higher in males. The overall sex ratio was M:F = 1.06:1, indicating a slight male bias (χ^2 test; $p < 0.05$). There was no significant difference between females and males regarding mean length (t-test, t = 0.154, $p > 0.05$) and weight (t-test, t = 0.276, $p > 0.05$).

The length–frequency relationship indicated that the 6.5 cm class size had the highest frequency, followed by the 8.0 cm class in both females and males, the 7.5 cm class in males, and the 5.5 cm class in females (Fig. 2).

The LWR indicated a positive allometric growth for both sexes (t-test, $p < 0.05$); the coefficient of determination (r^2) was 0.9762 for females, 0.9784 for males, and 0.9769 for the two sexes combined, indicating a strong correlation between length and weight. The length–weight equations were $W = 0.0036 \text{x} L^{3.4171}$ for females, $W = 0.0058 \text{x} L^{3.1757}$ for males, and $W = 0.0050 \text{x} L^{3.2534}$ for the combined sexes (Fig. 3). The calculated parameters and length characteristics of the length–weight relationships are given in Table 1.

The relationship between total length (cm) and total weight (g) for all samples is shown in Fig. 3. All regression models were highly significant ($p < 0.05$), with coefficients of determination (r^2) exceeding 0.970 for all sexes.

In the length–length relationship analysis, the present study found that the *b* value of the LLRs was greater than 1, indicating positive allometric growth for females, males, and the two sexes combined. The relationships among the three length measurements (TL–FL–SL) were highly correlated ($r^2 > 0.970$, $p < 0.001$). Conversions among length measurements (TL, FL, and SL) are given in Table 2.

Fulton's condition factor (*K*) for females, males, and combined sexes was 0.807±0.078, 0.820±0.072, and 0.812±0.074, respectively, showing no significant variation ($p > 0.05$).

The maximum length values for *A. dussumieri* recorded in the present study are higher than those reported in previous studies (Stern *et al.*, 2022; Afrand & Sourinejad, 2023; Çevik & Ergüden, 2026; Tab. 3). The enhanced growth and larger body size may be driven by nutrient-rich conditions associated with river inputs into the northeastern Mediterranean coastal waters of Türkiye, which likely boost primary production in the region.

Growth studies provide important scientific data for fisheries. The observed growth patterns showed positive allometry in the combined sample as well as the separate male and female samples, as the *b* value exceeded the isometric value (*b* = 3.0). The deviation

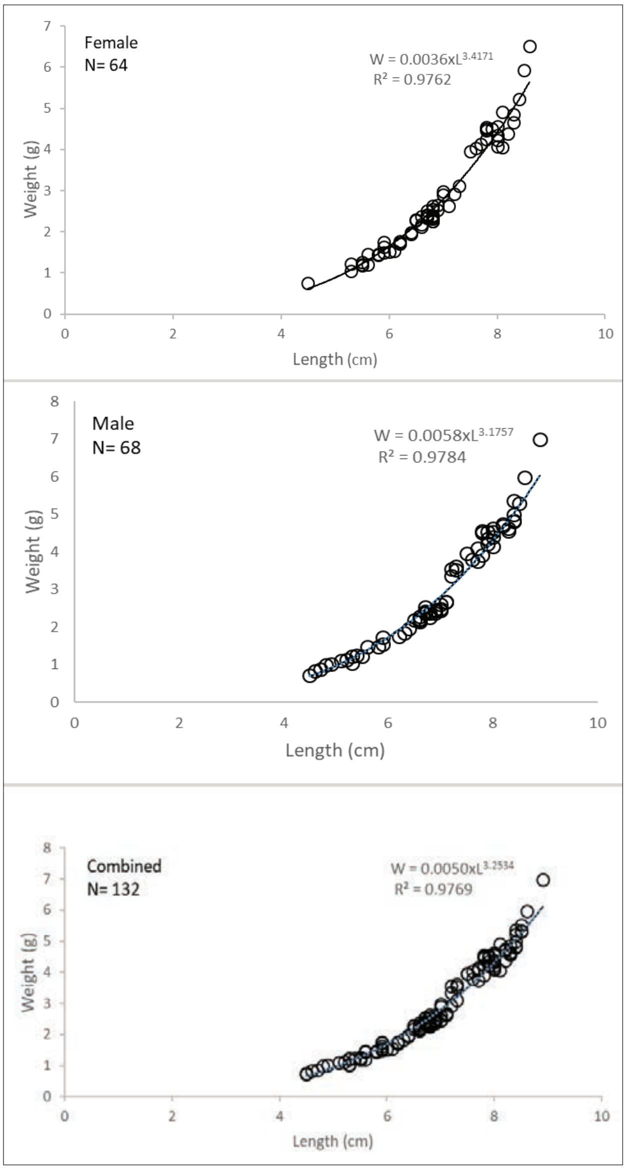

Fig. 3: Length–weight relationships for female, male, and combined of *Ambassis dussumieri* from the northeastern Mediterranean coast of Türkiye.
Sl. 3: Dolžinsko-masni odnosi za samice, samce in skupno populacijo vrste *Ambassis dussumieri* s severovzhodne sredozemske obale Turčije.

Tab. 2: Estimated parameters for the conversions between the length measurements (TL, FL, and SL in cm) of *Ambassis dussumieri* ***from the northeastern Mediterranean coast of Türkiye.***

Tab. 2: Ocenjeni parametri za pretvorbe med merami dolžine (TL, FL in SL v cm) pri primerkih vrste *Ambassis dussumieri* ***s severovzhodne sredozemske obale Turčije.***

Sample	No. of individuals	Equation	Constant a	Slope b	SE (b)	r^2
Female	64	TL = a + bSL	0.212	1.033	0.021	0.974
		SL = a + bFL	0.204	0.831	0.024	0.971
		FL = a + bTL	-0.379	1.106	0.016	0.971
Male	68	TL = a + bSL	0.215	1.023	0.018	0.980
		SL = a + bFL	0.141	0.866	0.015	0.982
		FL = a + bTL	-0.343	1.097	0.019	0.980
Combined	132	TL = a + bSL	0.236	1.013	0.014	0.977
		SL = a + bFL	0.149	0.862	0.024	0.971
		FL = a + bTL	-0.358	1.100	0.013	0.973

of the *b* value for the combined sexes (3.253) was statistically significant ($p < 0.05$).

Bagenal & Tesch (1978) stated that *b* values can vary primarily depending on sample size, length interval, study season, sea conditions, and environmental conditions at the sampling location. Our results are not fully comparable with previous records, since not all of them included LWR studies for this species. However, a comparison between the previously reported length–weight parameters and those obtained in our study is provided in Table 3.

Additional factors are known to influence the length–weight parameters in fish, including gonad maturity, stomach fullness, health, and preservation techniques (Bagenal & Tesch, 1978; Wootton, 1998). Our length and weight data were collected during autumn and winter, however, the season and other above-mentioned factors were not considered in the study.

Fulton's condition factor (*K*), an expression of the relative fatness of fish, which indicates the interaction between biotic and abiotic factors and general fish condition, was 0.812 for the sexes combined. This factor is suitable for comparing the condition of fish of the same species across seasons, locations, or sexes, and reflects ecological and physiological conditions, providing information on the fish's physiological state. This metric also relates to fish welfare in terms of reproduction and nutrition (Le Cren, 1951).

In our study, the condition value was less than 1 ($K < 1$), possibly reflecting food/prey scarcity, increased competition, or environmental factors, including water quality. Nevertheless, our findings indicate that the population of *A. dussumieri* primarily exhibited allometric growth (+), which suggests that the northeastern Mediterranean waters of Türkiye still provide, on average, a suitable feeding environment for this species.

Prior to this study, no information was available on the length–weight and length–length relationships or condition factor of *A. dussumieri* along the Mediterranean coasts, and no biological data on this species were available in the FishBase database. Therefore, this study provides the first comprehensive information on the species in Mediterranean waters.

Tab. 3: Geographic comparison of maximum length and length–weight relationship data for *Ambassis dussumieri.*

Tab. 3: Geografska primerjava največje dolžine in podatkov o dolžinsko-masnem odnosu za vrsto *Ambassis dussumieri****.***

Study	Locality	Country	Samples	No. of individuals	Length Type	L_{min}-L_{max} (cm)	W_{min}-W_{max} (g)
Stern *et al.* (2022)	Eastern Mediterranean Sea	Israel	Combined	6	TL	3.94–4.88	0.51–0.97
Afrand & Sourinejad (2023)	Persian Gulf, Khuran Strait	Iran	Combined	2	TL	4.98–5.20	-
Çevik & Ergüden (2026)	Northeastern Mediterranean Sea	Türkiye	Combined	4	TL	7.17–8.65	3.46–6.67
This study	Tuzla coast, northeastern Mediterranean Sea	Türkiye	Combined	132	TL	4.50–8.90	0.72–6.99

It also contributes to scientific knowledge of the Mediterranean Sea by documenting a newly recorded fish species and supporting the inclusion of its biological parameters in the FishBase database.

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DOLŽINSKO-MASNI ODNOS MED DOLŽINO IN KONDICIJSKIM FAKTORJEM PRI VRSTI *AMBASSIS DUSSUMIERI* CUVIER, 1828, V SEVEROVZHODNEM SREDOZEMSKEM MORJU, TURČIJA

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POVZETEK

Avtorja obravnavata prve podatke o dolžinsko-masnem odnosu (LWR), razmerju med dolžinami (LLR) in kondicijskem faktorju (K) za Malabarskega steklenega ostriža Ambassis dussumieri *v severovzhodnem Sredozemskem morju (obala Tuzle, Turčija). Pregledala sta skupaj 132 osebkov (68 samcev in 64 samic). Primerki obeh spolov so merili od 4,5 do 8,9 cm celotne dolžine (TL), od 3,7 do 7,7 cm viličaste dolžine (FL) in od 3,4 do 6,9 cm standardne dolžine (SL). Izračunane vrednosti b* so nakazovale pozitivno *alometrično rast za celotno populacijo (t-test, p < 0,05). Odnos med tremi merami dolžine (TL, FL in SL) je bil statistično zelo značilen (r² > 0,970). Povprečni koeficient kondicije (K) je bil 0,812 ± 0,074 za oba spola, brez pomembnih razlik med samicami in samci. Ti rezultati bodo uporabni za raziskave o biologiji tujerodnih vrst rib.*

Ključne besede: Malabarski stekleni ostriž, biološki parametri, Levantsko morje, Turčija

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UNEXPECTED OCCURRENCE OF PRUSSIAN CARP *CARASSIUS GIBELIO* (CYPRINIDAE) IN HOMA LAGOON (IZMIR BAY, AEGEAN SEA)

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ABSTRACT

On 24 February 2026, a female specimen of Carassius gibelio *was caught using a trammel net targeting grey mullets in Homa Lagoon, located on the coast of Izmir Bay, at a depth of 1 m. Homa is a highly saline environment, with salinity values ranging from 35.6 ‰ to 63.7 ‰. Therefore, the occurrence of* C. gibelio*, a potamodromous fish species, in its waters represents an unexpected phenomenon. This paper not only presents a remarkable occurrence of this invasive species in an unusual habitat, but also provides an additional contribution to the fish fauna records of Homa Lagoon, Izmir Bay.*

Key words: Salty lagoon, unusual habitat, measurement, Mediterranean

OCCORRENZA INASPETTATA DELLA CARPA DI PRUSSIA *CARASSIUS GIBELIO* (CYPRINIDAE) NELLA LAGUNA DI HOMA (BAIA DI IZMIR, MAR EGEO)

SINTESI

Il 24 febbraio 2026, un esemplare femmina di Carassius gibelio *è stato catturato mediante una rete da imbrocco utilizzata per la pesca dei cefali grigi nella laguna di Homa, situata sulla costa della Baia di Izmir, a una profondità di 1 m. Homa è un ambiente altamente salino, con valori di salinità compresi tra 35,6 ‰ e 63,7 ‰. Pertanto, la presenza di* C. gibelio*, una specie ittica potamodroma, nelle sue acque rappresenta un fenomeno inatteso. Questo lavoro non solo documenta una notevole presenza di questa specie invasiva in un habitat insolito, ma fornisce anche un ulteriore contributo ai dati sulla fauna ittica della laguna di Homa, nella Baia di Izmir.*

Parole chiave: laguna salata, habitat insolito, misurazione, Mediterraneo

INTRODUCTION

Cypriniformes are among the most evolutionarily successful freshwater fish, characterized by wide distribution, high abundance, and remarkable species diversity. This paper focuses on the Prussian carp *Carassius gibelio* (Bloch, 1782), as this species still retains a strong ability to colonize new areas and is well known for invading diverse water bodies (Afanasyev *et al.*, 2025). Nowadays, *C. gibelio* has attracted considerable interest from aquatic biologists. It is an invasive species with a widespread distribution resulting from introductions and translocations across most European countries (Perdikaris *et al.*, 2012).

Carassius gibelio inhabits a wide variety of still water bodies and lowland rivers usually associated with submerged vegetation or periodic flooding. It displays strong tolerance to low oxygen concentrations and pollution. Its diet includes plankton, benthic invertebrates, plant material, and detritus, *C. gibelio* spawns on submerged vegetation in shallow, warm shores and is capable of developing from unfertilized eggs (gynogenesis). Its life span reaches up to about 10 years. Length at maturity is 10.3 cm, the maximum total length is 46.6 cm (common total length: 20.0 cm), and the maximum published weight is 3.0 kg (Froese & Pauly, 2025).

Carassius gibelio is distributed across Europe and Asia. Clear and definite data on its native range in Europe are lacking due to historical introductions, confusion with *Carassius auratus*, and complex breeding patterns. At present, the species is widely distributed and commonly stocked together with *Cyprinus carpio*, which is transported throughout Europe. It is absent from the northern Baltic basin, Iceland, Ireland, Scotland, and Mediterranean islands (Froese & Pauly, 2025). The species has minimal commercial value, which makes it an undesirable target for fisheries (Perdikaris *et al.*, 2012).

The Prussian carp is listed by the IUCN as one of the 100 worst invasive species in the world. As vector, they were introduced to Türkiye from Europe for fish release purposes. Following its introduction, *C. gibelio* spread rapidly and uncontrollably to other lakes (Uysal & Boz, 2018). This study presents unexpected field data on this species' appearance in a new region, specifically, its first observation in a high-salinity lagoon basin in Izmir Bay, Aegean Sea.

Fig. 1: *Carassius gibelio* **caught from Homa Lagoon (ESFM-PIS/2026-01) with a black peritoneum. Scale bar: 50 mm.**
Sl. 1: *Carassius gibelio* **(srebrni koreselj), ujet v laguni Homa (ESFM-PIS/2026-01), s črnim peritonejem (trebušno mreno). Merilo: 50 mm.**

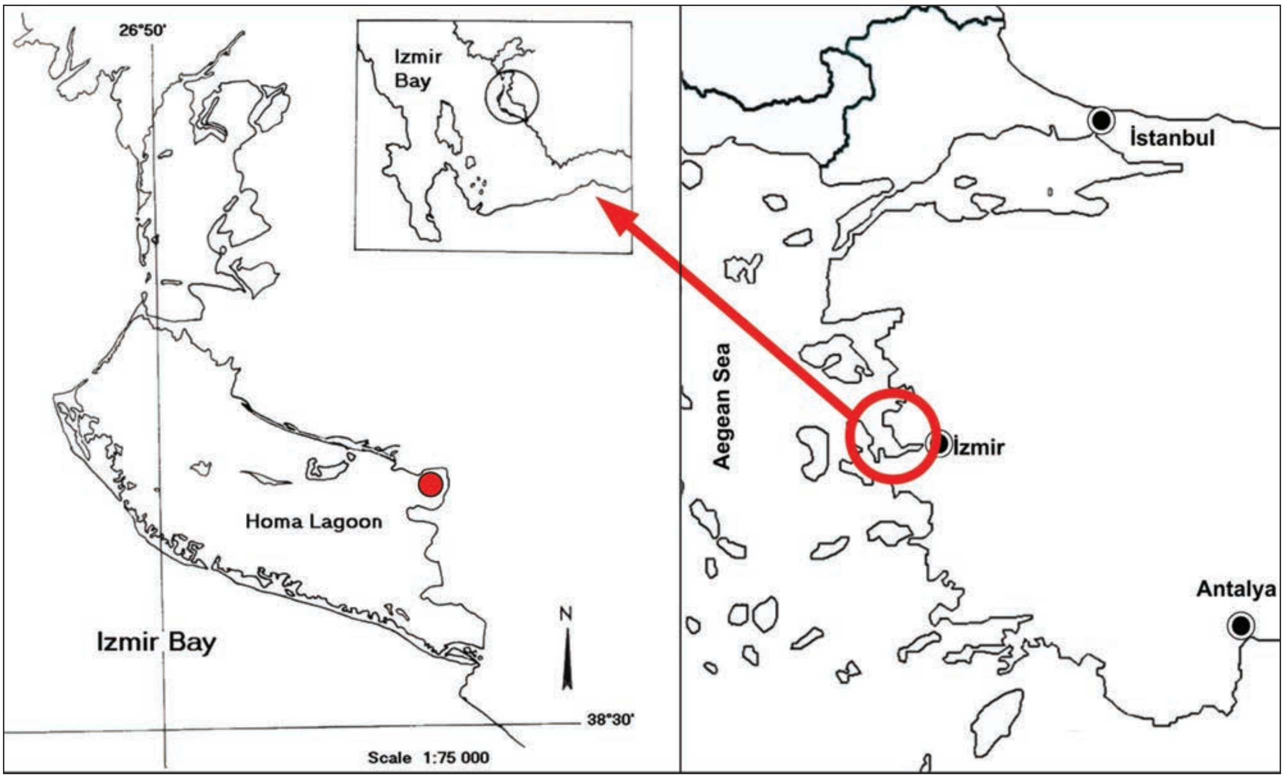

Fig. 2: Sampling site (red dot) of *Carassius gibelio* ***in Homa Lagoon, Izmir Bay, Aegean Sea.***
Sl. 2: Lokacija vzorčenja (rdeča pika) za vrsto *Carassius gibelio* ***v laguni Homa, Izmirski zaliv, Egejsko morje.***

MATERIAL AND METHODS

On 24 February 2026, a female specimen of *Carassius gibelio* (Fig. 1) was caught using a trammel net targeting grey mullets in Homa Lagoon, located on the coast of İzmir Bay (38°32′00″ N, 26°52′51″ E) at a depth of 1 m (Fig. 2).

Homa Lagoon, situated near the Gediz River delta in the northeastern part of the Izmir Bay, is an important wetland covering an area of approximately 1824 hectares and serving as a feeding, growth, and breeding area for many fish and bird species. Since 1986, the lagoon has been used as an experimental fishing area by the Faculty of Fisheries of Ege University. It has also been designated as a wildlife conservation area since 1984 and has been protected under the Ramsar Convention since 1998 (Akyol, 2005). A total of 39 fish species have been identified within the lagoon to date (Alpbaz & Kınacıgil, 1988; Acarlı *et al*., 2009). The sample fish was fixed in 6% formaldehyde solution and preserved in the fish collection of the Faculty of Fisheries, Ege University (ESFM-PIS/2026-01). Terminology followed Soto *et al*. (2024), who evaluated the various terms used in invasion science and proposed a simplified and standardized nomenclature.

RESULTS AND DISCUSSION

The specimen was identified as a *Carassius gibelio* based on the following characters: body silvery-brown, peritoneum black; last simple anal and dorsal-fin rays strongly serrated; 29 scales along the lateral line (Fig. 1). Selected morphometric measurements and proportions expressed as percentages of total length (TL%) are presented in Table 1.

Carassius gibelio was first reported in Türkiye from Lake Gala in the 1980s (Baran & Ongan, 1988). Subsequently, the species spread to almost all inland waters of Thrace and Anatolia (Ekmekçi *et al*., 2013). Since then, the Prussian carp has probably become the most dominant invasive non-native fish species and is now considered naturalized in more than 230 lakes, rivers, streams, ponds, and reservoirs throughout Türkiye (Ekmekçi *et al*., 2013; Yerli *et al*., 2014). The dominance of *C. gibelio* is attributed to its broad environmental tolerance and flexible adaptive biological strategies, including omnivorous feeding habits, exploitation of variable habitats (slow-running lotic, lentic, and transitional systems with low salinity), intense reproductive activity, and active competition for food, spawning sites, and spawning substrates (Pardikaris *et al*., 2012). It is

Tab. 1: Morphometric measurements and proportions expressed as percentages of total length (TL%) for *Carassius gibelio* ***captured in Homa Lagoon, Izmir Bay, Aegean Sea.***
Tab. 1: Morfometrične meritve in deleži, izraženi kot odstotki celotne dolžine (TL %), za primerek vrste *Carassius gibelio****, ujetega v laguni Homa, Izmirski zaliv, Egejsko morje.***

Morphometrics	**mm**	**TL%**
Total length (TL)	255	-
Standard length (SL)	210	82.4
Head length (HL)	55	21.6
Eye diameter	11	4.3
Snout length	15	5.9
Body depth	81	31.8
Predorsal length	94	36.9
Preanal length	155	60.8
Prepectoral length	52	20.4
Meristic counts		
Dorsal fin	III + 17	
Anal fin	III + 5	
Pectoral fin	18	
Ventral fin	I + 8	
Lateral line	29	
Weight (g)	305	

therefore not surprising for the highly adaptable Prussian carps to occur in some Turkish brackish lagoons, such as Liman or Karaboğaz, Akyatan, and Peso lagoons (Ekmekçi *et al.*, 2013). These lagoons are characterized by slightly saline (brackish) waters. Liman Lagoon, which is connected to the Black Sea, has salinity levels between 0.24‰ and 13.19 ‰ (Macun, 2014). Salinity in Akyatan Lagoon in the northeastern Mediterranean region varies between 3.3‰ and 35.34‰ (average 15.64 ± 6.4‰) (Akyol & Manaşırlı, 2023). According to Akyol and Ceyhan (2010), several carp specimens accidentally caught in 2004 were recorded from Peso Lagoon (Edirne, northern Aegean Sea), where salinity dropped to 0.04‰–0.09‰ in December during the rainy season. Among these lagoons, Homa is the most saline, with values ranging from 35.6‰ to 63.7‰ (Başdemir, 2017). Perdikaris *et al.* (2012) and references therein reported that *C. gibelio* was distributed in many continental freshwaters (lotic and lentic ecosystems) as well as transitional coastal waters with low salinity. Therefore, the occurrence of *C. gibelio C. gibelio* as a potamodromous fish in the highly saline Homa Lagoon represents an unexpected phenomenon. The area where the fish was observed may have lower salinity levels compared to other parts of the lagoon due to freshwater inputs through drainage canals.

C. gibelio individuals inhabiting lakes may migrate to river estuaries during winter to avoid low dissolved oxygen conditions (Froese & Pauly, 2025). Additionally, the heavy rainfall and flooding events in January and February 2026 may have facilitated the transport of this fish to the study area. It is therefore possible that the specimen reached the estuary of the Gediz River and subsequently moved through the canals into the lagoon. A similar situation was reported from the Akçapınar Stream delta, Gökova Bay (southeastern Aegean Sea) in 2020, where a specimen of *Capoeta aydinensis* (Cyprinidae) was spotted at a depth of 1.5 m, having been transported into the marine environment during floods caused by heavy rainfall (Akyol *et al.*, 2020). Another possible explanation is foraging activity in brackish lagoons. Bohlen (1999) noted that several freshwater fishes migrate to brackish waters for feeding and growth but return to lower-salinity waters for spawning.

In conclusion, a *C. gibelio* individual, potentially displaced during flood events caused by heavy rainfall or having entered the area during foraging activity, has been recorded for the first time from an unexpected saline habitat. Therefore, this paper not only reports a remarkable occurrence of this non-indigenous species in an unusual environment, but also contributes to the fish fauna records of Homa Lagoon, Izmir Bay. Further surveys are needed to determine whether this record represents a single sporadic occurrence or a more persistent presence.

NEPRIČAKOVANI POJAV SREBRNEGA KORESLJA *CARASSIUS GIBELIO* (CYPRINIDAE) V LAGUNI HOMA (IZMIRSKI ZALIV, EGEJSKO MORJE)

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POVZETEK

*V laguni Homa na obali Izmirskega zaliva je bila 24. februarja 2026 ujeta samička srebrnega koreslja (*Carassius gibelio*). Riba je bila ujeta na globini enega metra s troslojno stojno mrežo, namenjeno lovu cipljev. Pojav je nenavaden, saj je laguna Homa izrazito slano okolje, kjer se vrednosti slanosti gibljejo med 35,6 ‰ in 63,7 ‰. Srebrni koreselj je namreč potamodromna ribja vrsta, ki je v teh vodah ne bi pričakovali. Ta članek ne prikazuje le izjemnega pojava te invazivne vrste v nenavadnem habitatu, ampak prinaša tudi dodaten prispevek k zapisom o favni rib v laguni Homa v Izmirskem zalivu.*

Ključne besede: slana laguna, nenavaden habitat, meritve, Sredozemlje

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SREDOZEMSKE HRUSTANČNICE

SQUALI E RAZZE MEDITERRANEE

MEDITERRANEAN SHARKS AND RAYS

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PRECOPULATORY BEHAVIOUR OF *PTEROPLATYTRYGON VIOLACEA* (MYLIOBATIFORMES: DASYATIDAE) IN THE NORTHWESTERN MEDITERRANEAN

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ABSTRACT

The pelagic stingray, Pteroplatytrygon violacea*, is a batoid belonging to the family Dasyatidae, whose reproduction remains poorly understood. This paper describes two rare precopulatory behaviour events involving two adult pairs observed in French and Spanish waters in August 2018. It identifies distinct behavioural stages: grasping, pairing, body rotation, and clasper flexion. The persistent inverted posture of the female suggests a potential male-induced tonic immobilization, a behaviour not previously documented in pelagic rays. These observations provide the first well-documented account of precopulatory behaviour in the pelagic stingray and suggest possible reproductive adaptations in this highly migratory elasmobranch species.*

Key words: pelagic stingray, copulation, reproduction, France, Spain, Mediterranean

COMPORTAMENTO PRECOPULATORIO DI *PTEROPLATYTRYGON VIOLACEA* (MYLIOBATIFORMES: DASYATIDAE) NEL MEDITERRANEO NORD-OCCIDENTALE

SINTESI

Il trigone viola, Pteroplatytrygon violacea*, è un batoideo appartenente alla famiglia Dasyatidae, la cui riproduzione rimane ancora poco conosciuta. Lo studio descrive due rari episodi di comportamento precopulatorio che hanno coinvolto due coppie adulte osservate nelle acque francesi e spagnole nell'agosto 2018. Vengono identificate diverse fasi comportamentali distinte: presa, formazione della coppia, rotazione del corpo e flessione dei pterigopodi. La persistente postura invertita della femmina suggerisce una possibile immobilizzazione tonica indotta dal maschio, un comportamento mai documentato in precedenza nelle razze pelagiche. Queste osservazioni forniscono la prima descrizione ben documentata del comportamento precopulatorio nel trigone viola e suggeriscono possibili adattamenti riproduttivi in questa specie di elasmobranco altamente migratrice.*

Parole chiave: trigone viola, copulazione, riproduzione, Francia, Spagna, Mediterraneo

INTRODUCTION

The pelagic stingray, *Pteroplatytrygon violacea* (Bonaparte, 1832), is the only pelagic species within the family Dasyatidae (Mollet, 2002; Last *et al.*, 2016). It is widely distributed throughout the world's oceans (Mollet, 2002) and well-known in the Mediterranean (Barone *et al.*, 2022). Unlike other stingrays, this species inhabits pelagic and oceanic habitats ranging from the margins of continental and insular shelves to the open ocean, typically within the upper 100 m (Ebert & Stehmann, 2013). However, a recent study has shown that the bathymetric range of *P. violacea* can extend to depths of up to 480 m (Poisson *et al.*, 2024). Like in other Myliobatiformes, such as mobulids, observing the reproductive behaviour is particularly challenging due to the species' elusive occurrence in the Mediterranean (Ziani *et al.*, in press). The high mobility of *P. violacea* within the water column likely drives behavioural adaptations associated with its lifestyle, including reproductive adaptations that ensure successful copulation, as observed in other pelagic elasmobranch species (Pratt *et al.*, 2001; Duffy & Tindale, 2018; McCallister *et al.*, 2020). This paper reports two well-documented observations of *P. violacea* pairs exhibiting precopulatory courtship behaviour.

MATERIAL AND METHODS

At 8:30 p.m. on 8 August 2018, an interaction between two individuals of *P. violacea* (pair 1) was recorded just beneath the surface by a free diver using a GoPro Hero 5, approximately 5 km offshore from Cap Sicié, France (Fig. 1). The interaction lasted one minute and involved a mature adult male-female pair, each approximately 40 cm in disc width. The depth at the site was 80 m, with clear conditions and weak currents. No other biological activity was recorded at the time, and the diver was alone with the pair of rays. The second sighting (pair 2) was recorded on 29 August 2018 by a Spanish free diver off Cape de Creus (Catalonia, Spain), a few kilometres from the coast, also in clear waters (Fig. 1; 3Cat, 2018). The two video sequences were used for subsequent behavioural analysis.

RESULTS AND DISCUSSION

The two *P. violacea* individuals of pair 1 were estimated to be sexually mature based on the disc width of approximately 40 cm and the length of the male's claspers (Fig. 2). The recorded behaviour lasted one minute and did not include copulation.

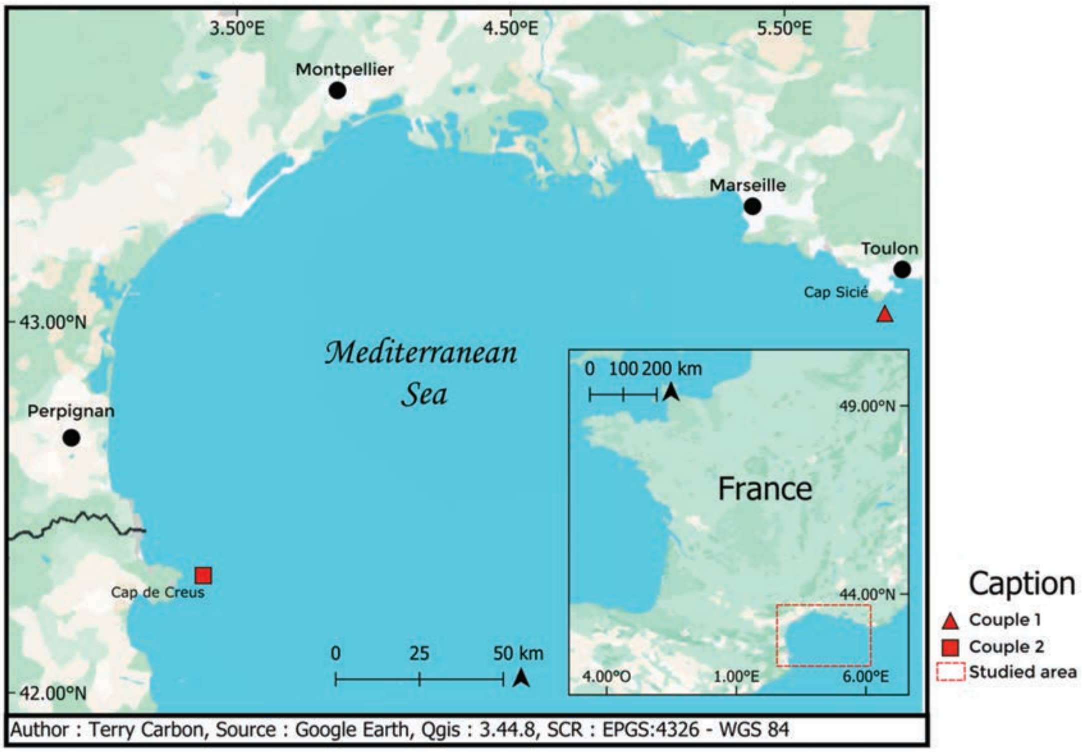

Fig. 1: Geolocation of paired* Pteroplatytrygon violacea *off the French (pair 1) and Spanish (pair 2) coasts.
Sl. 1: Geolokacija parov vijoličnega morskega biča (*Pteroplatytrygon violacea*) ob francoski (1. par) in španski (2. par) obali.

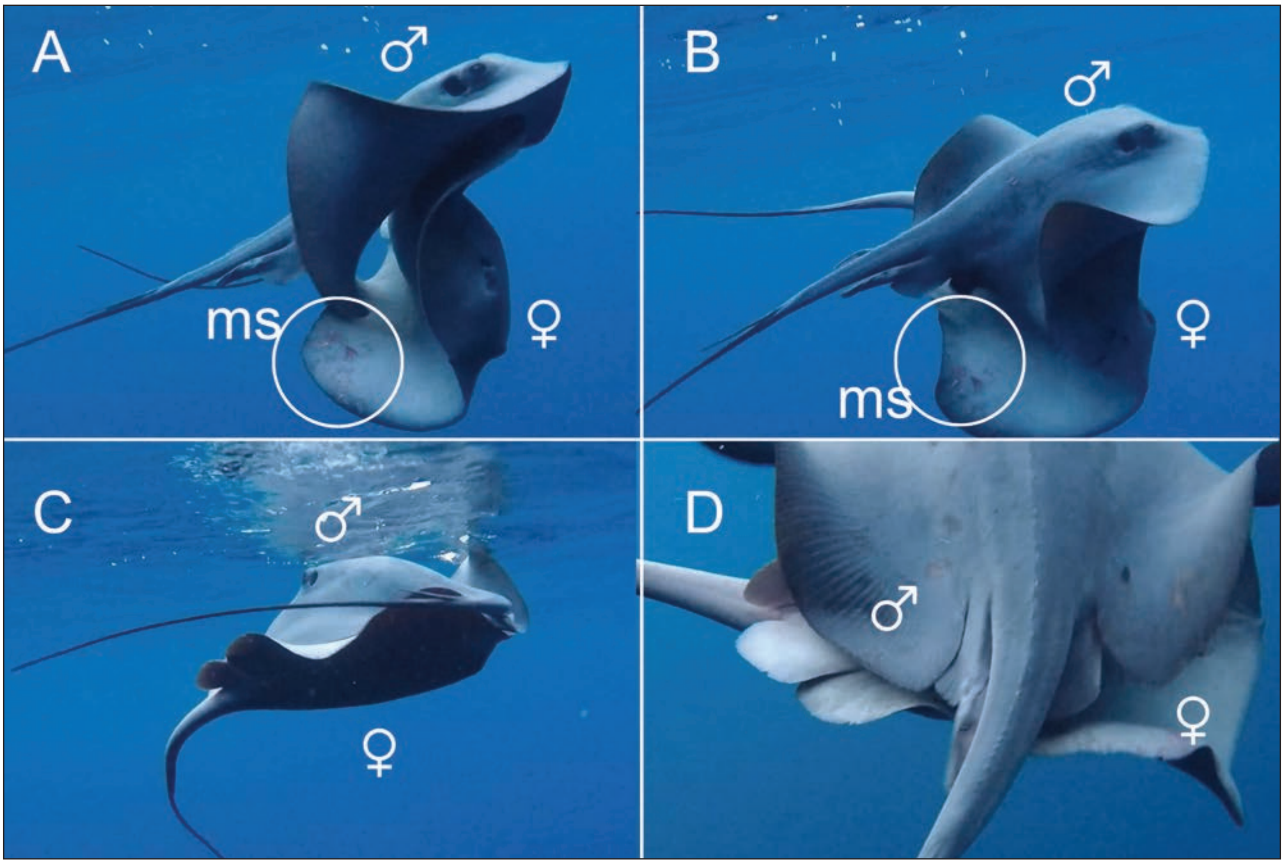

Fig. 2: Behavioural sequences observed during male–female interaction: (a) the male approaches the female and firmly grasps the right pectoral apex of her disc with his mouth; (b) the male holds the female's disc in his mouth and leans against her ventral surface so that they swim belly to belly; (c) still holding the female's disc between his jaws, the male spins around her in an anti-clockwise direction while maintaining a firm ventral contact, and positions her beneath him in an inverted posture; (d) close-up of the pelvic areas of paired individuals: as the male circles the female's body, he begins to erect his claspers, directing them inwards via flexion upon reaching the female's cloacal region. ms = mating scars on the apex of the female's disc left by the male's jaws during biting to secure grip. (Still images extracted from video footage provided by T. Vandezande).

Sl. 2: Vedenjske sekvence, opažene med interakcijo med samcem in samico: (a) samec se približa samici in z usti trdno zagrabi desno konico plavuti (apeks) njenega diska; (b) samec drži samičin disk v svojih ustih in se nasloni na njeno trebušno površino, tako da plavata s trebuhom ob trebuhu; (c) samec, ki še vedno drži samičin disk med čeljustmi, se zavrti okoli nje v smeri proti urinemu kazalcu, pri čemer ohranja tesen trebušni stik, in jo namesti podse v obrnjen položaj; (d) bližnji posnetek pelvičnih predelov parjenih osebkov: ko samec kroži okoli samičinega telesa, začne dvigovati svoja pterigopoda (klasperja) in ju z upogibanjem usmerja navznoter, ko doseže samičino območje kloake. ms = paritvene brazgotine na konici samičinega diska, ki so jih pustile samčeve čeljusti med grizenjem za zagotovitev oprijema. (Slike so izrezane iz videoposnetka, ki ga je posredoval T. Vandezande).

Direct observations of mating in elasmobranchs are rare (Gordon, 1993; Duffy & Tindale, 2018; McCallister *et al.*, 2020) and studies on the reproductive behaviour of myliobatiform ray are particularly limited due to the rarity and elusiveness of such events in the field (Yano *et al.*, 1999; Duffy & Tindale, 2018; Yamaguchi *et al.*, 2021; Ziani *et al.*, in press). Benthic rays typically use the substrate for stabilisation during mating (Pratt *et al.*, 2001; Morson & Morrissey, 2008). In contrast, pelagic elasmobranchs such as *P. violacea* must maintain pairing within the water column (Fig. 2) without external support (Pratt *et al.*, 2001; Henningsen *et al.*, 2004).

Mating in the water column imposes additional environmental constraints, requiring precise coordination to achieve copulation in the absence of a stable substrate. This includes close swimming, mating bites, and alignment of the pelvic regions. The male must actively and firmly grasp the female's disc to facilitate ventral pairing (Fig. 2) and ensure correct pelvic positioning during copulation. Pectoral biting appears to be particularly important in pelagic species, as it stabilises both partners within the water column (Hamlett, 2005; Duffy & Tindale, 2018). Documented mating sequences in rays such as *Mobula birostris*, including chasing, pectoral biting, copulation, resting, and separation, highlight the behavioural adaptations required for successful mating in open water (Yano *et al.*, 1999, Duffy & Tindale, 2018; McCallister *et al.*, 2020; Ziani *et al.*, in press). Indeed, long-term studies of mobulid courtship and mating reveal elaborate multistage sequences — from male following, through precopulatory positioning, to copulation and postcopulatory separation — that can involve dozens of individual events and distinct behavioural phases across species (Stevens *et al.*, 2018). The consistency of these stages across different mobulid taxa suggests that coordinated body alignment and sustained physical contact are fundamental to reproductive success in pelagic elasmobranchs. Observing such complex interactions in the open ocean is inherently challenging due to the mobility of the animals, the lack of stable substrates, and the difficulty of underwater observation. Therefore, detailed field observations, such as those reported here, offer rare and valuable insights into the reproductive ecology of pelagic stingrays, providing a unique contribution to our understanding of their mating strategies and behavioural adaptations under natural conditions.

A notable observation from the present video is the constant inverted position maintained by the female *P. violacea*, suggesting possible male-induced tonic immobilisation. Although this behaviour has not yet been reported in pelagic rays, it is well documented in several shark species, particularly *Triaenodon obesus* (Rüppell, 1837), where dorsoventral inversion and physical contact can induce a temporary paralysis that facilitates copulation (Wourms, 1977; Henningsen *et al.*, 2004; Ritter & Amin, 2019). While the observed sequence does not provide direct proof of active catalepsy in *P. violacea*, the female's sustained inverted and passive posture, combined with the male's biting and lateral movement, suggest a possible strategy to enhance stability within the water column, potentially reducing resistance and improving cloacal alignment for copulation. Previous studies on *M. birostris* and *Aetobatus narinari* have reported only partial inversions or twisting during pelvic interactions (Tricas, 1980; Yano *et al.*, 1999). The behaviour observed here may therefore represent the first evidence of a cataleptic posture associated with precopulatory activity in the pelagic stingray. Clasper mobility and control are also likely critical for successful copulation in such a highly dynamic, three-dimensional environment (Yano *et al.*, 1999; Fitzpatrick *et al.*, 2012; Trinajstic *et al.*, 2015).

A recent study showed that, with regard to pelagic stingrays, the elevated catch per unit effort in fisheries from July to September in the western Mediterranean Sea may result from the species' seasonal aggregating behaviour during spring and summer associated with the reproductive cycle (Poisson *et al.*, 2024). According to Poisson *et al.* (2024), individuals of *P. violacea* appear to aggregate on the continental shelf in the western Mediterranean Sea during summer, moving southwards in early autumn, which may correspond to spawning behaviour and overwintering. Although *P. violacea* is a pelagic and oceanic batoid (Ebert & Stehmann, 2013), females are also believed to move into inshore waters for parturition (Poisson *et al.*, 2024). The pelagic stingray is currently listed as Least Concern both in the Mediterranean Sea (Baum *et al.*, 2016) and across its global range (Kyne *et al.*, 2018); however, further research is required to better understand the seasonal movement patterns of individuals, particularly mature adults and newborns, in order to mitigate mortality caused by bycatch.

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We would like to thank Mr. Thomas Vandezande, the French free diver, for sharing his footage recorded off Cap Sicié (Var, France).

PREDKOPULACIJSKO VEDENJE VIJOLIČNEGA MORSKEGA BIČA (*PTEROPLATYTRYGON VIOLACEA*) (MYLIOBATIFORMES: DASYATIDAE) V SEVEROZAHODNEM SREDOZEMLJU

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POVZETEK

*Vijolični morski bič (*Pteroplatytrygon violacea*) je skat, ki pripada družini morskih bičev (Dasyatidae) in katerega razmnoževanje ostaja slabo raziskano. Avtorji poročajo o dveh redkih primerih predkopulacijskega vedenja, v katera sta bila vključena dva odrasla para, opazovana v francoskih in španskih vodah avgusta 2018. Opredelili so različne stopnje vedenja: grabljenje (oprijemanje), združevanje v par, rotacijo telesa in upogibanje pterigopodov (klasperjev). Dolgotrajna obrnjena drža samice kaže na možno tonično imobilizacijo, ki jo je izzval samec, kar je vedenje, ki ga pri pelagičnih skatih prej še niso dokumentirali. Ta opažanja prinašajo prvi dobro dokumentirani prikaz predkopulacijskega vedenja pri vijoličnem morskem biču in kažejo na možne prilagoditve razmnoževanja pri tej izrazito selitveni vrsti hrustančnic.*

Ključne besede: vijolični morski bič, parjenje, razmnoževanje, Francija, Španija, Sredozemsko morje

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DISTRIBUTION OF *ODONTASPIS FEROX* IN THE MEDITERRANEAN SEA: INSIGHTS FROM SPATIAL AND TEMPORAL ANALYSES

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ABSTRACT

This study provides an updated synthesis of the occurrence and distribution of smalltooth sandtiger shark, Odontaspis ferox*, in the Mediterranean Sea, based on 46 records spanning the period 1964–2025. Occurrence records were found to be unevenly distributed across the basin, with a pronounced concentration in the Aegean Sea (GSA 22), which accounted for nearly half of all records. Kernel density estimation further supported this spatial clustering. Temporal analysis revealed a significant increase in the annual number of records, reflecting both intensified research efforts and a growing contribution of citizen science facilitated by digital technologies. Although some records from Libyan and Syrian waters could not be included due to the lack of precise locality data, the present compilation represents a substantial increase compared to earlier assessments.*

Key words: smalltooth sandtiger, distribution, hot spot, kernel density estimation, eastern Mediterranean

DISTRIBUZIONE DI *ODONTASPIS FEROX* NEL MAR MEDITERRANEO: APPROFONDIMENTI DA ANALISI SPAZIALI E TEMPORALI

SINTESI

Lo studio fornisce una sintesi aggiornata della presenza e distribuzione del cagnaccio, Odontaspis ferox*, nel Mediterraneo, basata su 46 segnalazioni che coprono il periodo 1964–2025. Le segnalazioni risultano distribuite in modo non uniforme nel bacino, con una marcata concentrazione nel Mar Egeo (GSA 22), che rappresenta quasi la metà di tutti i ritrovamenti. L'analisi tramite stima della densità kernel ha ulteriormente confermato questa distribuzione spaziale. L'analisi temporale ha evidenziato un aumento significativo del numero annuale di segnalazioni, riflettendo sia l'intensificarsi degli sforzi di ricerca sia il crescente contributo della citizen science, facilitato dalle tecnologie digitali. Sebbene alcune segnalazioni provenienti dalle acque libiche e siriane non abbiano potuto essere incluse a causa della mancanza di dati precisi sulla località, la presente raccolta rappresenta un incremento sostanziale rispetto alle valutazioni precedenti.*

Parole chiave: cagnaccio, distribuzione, hotspot, stima della densità kernel, Mediterraneo orientale

INTRODUCTION

The smalltooth sandtiger shark, *Odontaspis ferox* (Risso, 1810), is a large lamniform shark from the family Odontaspididae (Elasmobranchii: Lamniformes) (WoRMS Editorial Board, 2026). The species exhibits a cosmopolitan yet highly discontinuous distribution, occurring sporadically in the Atlantic, Pacific, and Indian Oceans, as well as in the Mediterranean Sea (Ebert *et al.*, 2021; Barone *et al.*, 2022). Despite its broad geographic range, *O. ferox* is rarely encountered and is typically known from isolated occurrence records. The species inhabits warm-temperate and tropical waters, occupying continental and insular shelves and upper slopes at depths ranging from approximately 10 m to more than 1,015 m, although it is more frequently recorded below 300 m (Ebert *et al.*, 2021). It is primarily demersal and often associated with steep and narrow topographic features, such as seamounts, islands, and the outer margins of continental shelves (Ebert *et al.*, 2021). The maximum recorded total length (TL) reaches up to 450 cm in females and 344 cm in males (Ebert *et al.*, 2021).

Within the Mediterranean Sea, the rarity of *O. ferox* is particularly pronounced. Fergusson *et al.* (2008) documented only 14 confirmed records from the basin during the period between 1964 and 2008, highlighting the exceptional infrequency of the species in the region. More recent studies have suggested that the number of Mediterranean records may be higher than previously assumed, likely reflecting increased observation effort and improved reporting rather than a true increase in abundance (Kabasakal *et al.*, 2024; Pyloridou *et al.*, 2025). Nevertheless, confirmed observations remain extremely limited, reinforcing the perception of *O. ferox* as one of the rarest lamniform sharks in the Mediterranean Basin.

Given the species' extreme rarity, fragmented distribution, and declining population trend—particularly within the semi-enclosed and heavily impacted Mediterranean Sea, each confirmed occurrence of *O. ferox* provides critical insight into its distribution and conservation status. The present study provides a comprehensive review of Mediterranean records of *O. ferox*, supported by spatial and temporal analyses, and establishes an objective framework for evaluating occurrence patterns across regions and over time. This approach highlights areas of regional importance, reveals trends in population dynamics, and strengthens the reliability of distributional assessments, providing robust, data-driven insights to guide conservation strategies for this highly threatened and elusive shark.

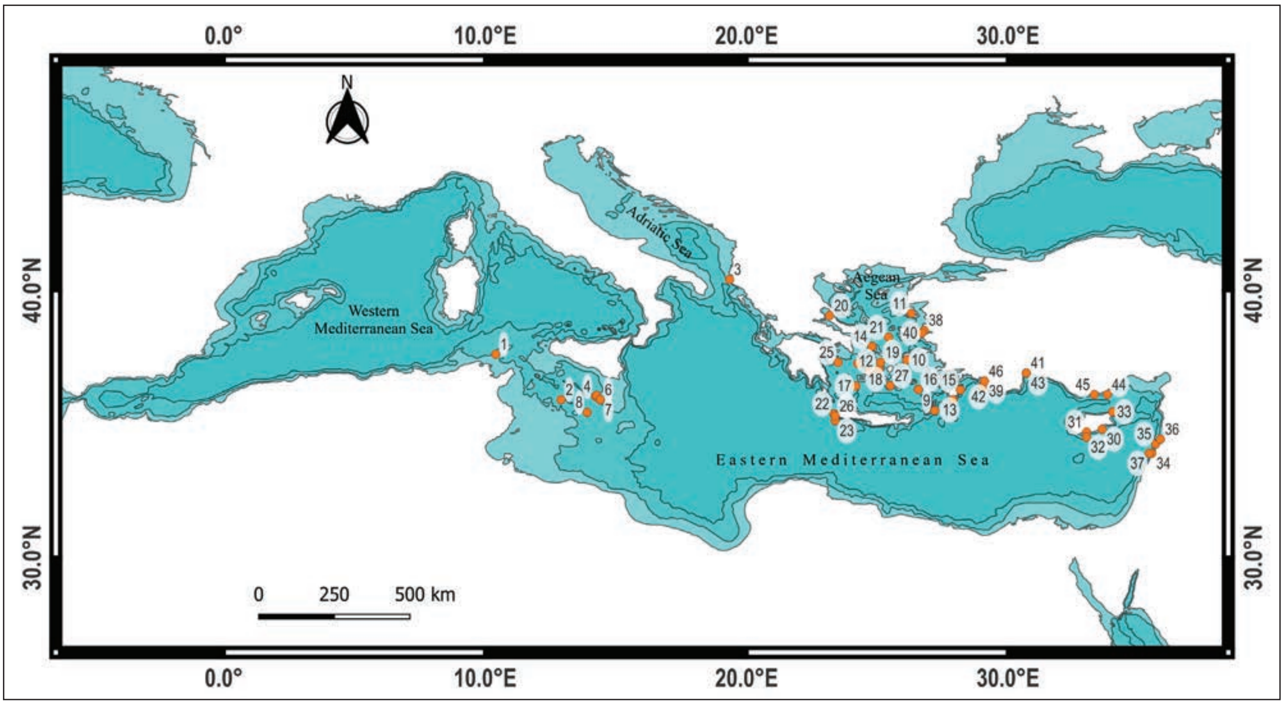

Fig. 1. Distribution of *Odontaspis ferox* **in the Mediterranean Sea based on published records; each dot represents a single published occurrence. The numbers in the labels correspond to those in the "No" column of Table 1.**
Sl. 1: Prikaz razširjenosti vrste *Odontaspis ferox* ***v Sredozemlju glede na objavljene vire. Vsaka pika označuje posamezen podatek o pojavljanju, številke napisov pa se ujemajo z zaporednimi številkami (stolpec »No.«) v tabeli 1.***

MATERIAL AND METHODS

Study Area

The Mediterranean Sea is recognized as a marine biodiversity hotspot situated between Africa, Europe, and Asia (Coll *et al.*, 2011). It is connected to the Atlantic Ocean through the Strait of Gibraltar, to the Sea of Marmara and the Black Sea via the Dardanelles, and to the Red Sea through the Suez Canal (Fig. 1). The basin reaches a maximum depth of 5,267 m and has an average depth of approximately 1,460 m. A shallow, approximately 400 m deep ridge in the Strait of Sicily separates the Mediterranean Sea into western and eastern sub-basins (Coll *et al.*, 2011; Serena & Soldo, 2024). According to the geographical subdivision of the Mediterranean Sea into Geographical Subareas (GSAs) proposed by the General Fisheries Commission for the Mediterranean (GFCM, 2018), the occurrence localities of additional records compiled from literature fall within GSAs 13 (Gulf of Hammamet), 15 (Malta), 16 (southern Sicily), 18 (southern Adriatic Sea), 22 (Aegean Sea), 23 (Crete), 24 (northern Levantine Sea), 25 (Cyprus), and 27 (eastern Levantine Sea).

Data Acquisition

To evaluate the occurrence of *O. ferox* within GSAs 13, 15, 16, 18, 22, 23, 24, 25, and 27, previously published records were compiled from the scientific literature (Geldiay, 1969; Fergusson *et al.*, 2008; Corsini-Foka, 2009; Kabasakal & Bayrı, 2019; Akbora *et al.*, 2019; Zaferiaki *et al.*, 2019; Bariche & Fricke, 2020; Kabasakal & Bilecenoğlu, 2020; Ben Amor *et al.*, 2020; Moutopoulos *et al.*, 2022; Soldo *et al.*, 2022; Kabasakal *et al.*, 2024; Pyloridou *et al.*, 2025). The literature review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page *et al.*, 2021). To avoid multiple inclusion of the same individual, the original source reporting each record was used as the primary reference.

A single database was compiled including all available Mediterranean records derived from peer-reviewed publications, incorporating information on locality (country and GSA), date of capture or observation, depth, reported total length (TL), sex, remarks (*e.g.*, fishing gear), and reference (Tab. 1). Distribution

Tab. 1. Review of* Odontaspis ferox *in the Mediterranean Sea based on published records.
Tab. 1: Pregled razširjenosti vrste* Odontaspis ferox *v Sredozemskem morju na podlagi objavljenih podatkov.

No	Year	Country	Location	GSA	Size (cm)	Sex	Depth (m)	Evidence	Remarks	Reference
1	1985	Italy	Skerki Bank, Sicilian Channel	16	410	F	N/A	Catch	Captured in demersal trawl fishery	Fergusson *et al.* (2008)
2	1991	Italy	Isola di Linosa, Pelagic Islands	16	230	F	10-40	Catch	Captured in bottom-set gillnet	Fergusson *et al.* (2008)
3	2021	Albania	Pasha Liman, Bay of Vlore	18	300	F	N/A	N/A	N/A	Soldo *et al.* (2022)
4	1998	Malta	Xlendi Bay, Gozo Island	15	353	F	100	Catch	Captured in bottom-set gillnet	Fergusson *et al.* (2008)
5	1999	Malta	Marsalforn, Gozo Island	15	400	N/A	N/A	N/A	N/A	Fergusson *et al.* (2008)
6	2002	Malta	N/A	15	298	N/A	N/A	Catch	Captured in bottom longline	Fergusson *et al.* (2008)
7	2003	Malta	N/A	15	382	F	N/A	Catch	Captured in bottom longline	Fergusson *et al.* (2008)
8	2020	Tunisia	Pantelleria Island	13	N/A	N/A	400-1,100	Catch	Captured in bottom longline	Ben Amor *et al.* (2020)
9	1968	Greece	Karpathos Island	22	340	F	N/A	Catch	Captured in demersal longline fishery	Fergusson *et al.* (2008)
10	1980	Greece	Ikaria Island	22	N/A	N/A	N/A	Catch	Photograph is published in the reference	Moutopoulos *et al.* (2022)
11	1981	Greece	Mytilene	22	N/A	N/A	N/A	Catch	Photograph is published in the reference	Moutopoulos *et al.* (2022)
12	2001	Greece	Sifnos Island, Cyclades	22	165	F	200	Catch	Captured in swordfish fishery	Fergusson *et al.* (2008)
13	2007	Greece	off southern Rhodes Island	22	250	N/A	ca. 70	Catch	Captured in demersal trawl fishery	Corsini-Foka (2009)
14	2011	Greece	Andros	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
15	2012	Greece	Rhodes	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)

16	2012	Greece	Kandelioussa	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
17	2012	Greece	Milos	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
18	2013	Greece	Paros	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
19	2014	Greece	Tinos	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
20	2015	Greece	Kastri	22	285	N/A	N/A	N/A	Captured in demersal fishery	Zaferiaki *et al.* (2019)
21	2015	Greece	Chios	22	377	N/A	N/A	N/A	Captured in demersal fishery	Zaferiaki *et al.* (2019)
22	2015	Greece	Crete	23	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
23	2017	Greece	Crete	23	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
24	2017	Greece	Kythnos	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
25	2021	Greece	Hydra	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
26	2022	Greece	Crete	23	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
27	2024	Greece	Amorgos	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
28	2025	Greece	Kandelioussa	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
29	2025	Greece	Kandelioussa	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
30	1999	Cyprus	off Larnaca	25	300	N/A	250	Catch	Captured in bottom-set gillnet fishery	Fergusson *et al.* (2008)
31	1999	Cyprus	off Limassol	25	300	N/A	100	Catch	Captured in demersal longline fishery	Fergusson *et al.* (2008)
32	1999	Cyprus	off Limassol	25	160	N/A	100	Catch	Captured in demersal longline fishery	Fergusson *et al.* (2008)
33	2018	Cyprus	off Yeni Erenköy	25	430	F	41	Catch	Captured during the fishing of *Seriola dumerili* by a local fisher and sold to a fish restaurant	Akbora *et al.* (2019)
34	1964	Lebanon	off Beirut	27	283	M	100	N/A	N/A	Fergusson *et al.* (2008)
35	1995	Lebanon	off Batroun	27	N/A	N/A	N/A	N/A	Occurrence record	Bariche & Fricke (2020)
36	2014	Lebanon	off Tripoli	27	N/A	N/A	N/A	N/A	Occurrence record	Bariche & Fricke (2020)
37	2015	Lebanon	off Beirut	27	N/A	N/A	N/A	N/A	Occurrence record	Bariche & Fricke (2020)
38	1969	Türkiye	İzmir Bay	22	N/A	N/A	N/A	N/A	Only locality record	Geldiay (1969)
39	2002	Türkiye	Fethiye Bay	22	200	N/A	N/A	Catch	Captured in demersal trawl fishery	Fergusson *et al.* (2008)
40	2004	Türkiye	Urla, İzmir Bay	22	190	F	30	Catch	Captured in artisanal fishery, type of the fishing gear not known	Fergusson *et al.* (2008)
41	2009	Türkiye	Antalya Bay	24	ca. 400	N/A	N/A	Catch	Type of fishing gear is unknown; the specimen cut to pieces and sold	Kabasakal *et al.* (2024)
42	2013	Türkiye	Fethiye Bay	22	ca. 120	F	N/A	Catch	Type of fishing gear is unknown; shipped to İstanbul Fishmarket and auctioned	Kabasakal *et al.* (2024)
43	2019	Türkiye	Antalya Bay	24	ca. 400	F	100 to 120	Catch	Captured in demersal trawl fishery	Kabasakal & Bayrı (2019)
44	2019	Türkiye	Taşucu, Mersin	24	ca. 400	F	N/A	Catch	Captured in demersal trawl fishery and sold	Kabasakal & Bilecenoğlu (2020)
45	2021	Türkiye	Bozyazı, Mersin	24	ca. 350	F	N/A	Catch	Captured in demersal trawl fishery and sold	Kabasakal *et al.* (2024)
46	2022	Türkiye	Fethiye Bay	22	272	M	N/A	Catch	Type of fishing gear is unknown; the specimen cut to pieces and sold; jaws are preserved in the personal collection of Mr. Erdi Bayrı	Kabasakal *et al.* (2024)

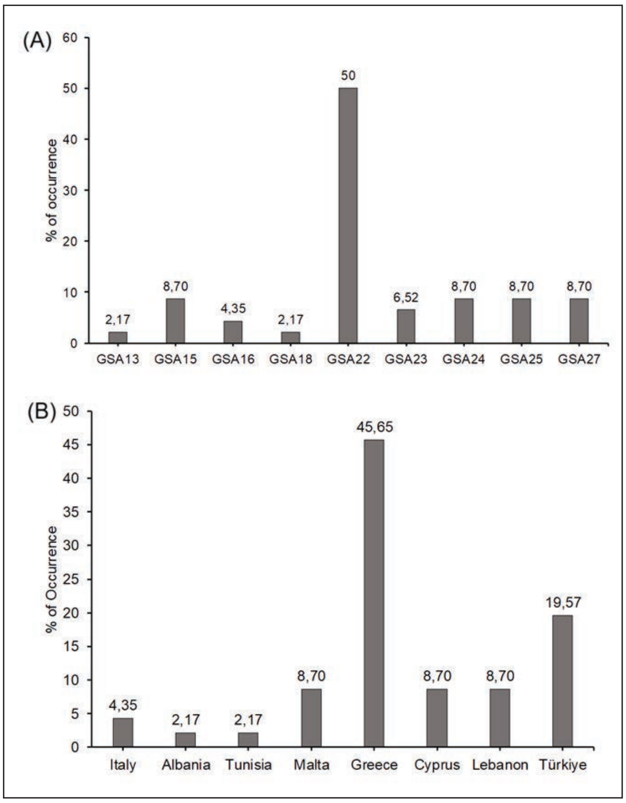

Fig. 2. Percentages of occurrence records by GSAs (a) and countries (b).
Sl. 2: Odstotni deleži podatkov o pojavljanju po geografskih podobmočjih (GSA) (a) in državah (b).

mapping was performed using centroid coordinates of published locality records, with each point representing a single individual, and visualized using the open-source geospatial software QGIS version 3.40.

Spatiotemporal Analysis

The geographical distribution of occurrence records was analyzed to identify hot and cold spots, under the assumption that areas with higher record densities may indicate suitable habitats (Bargnesi *et al.*, 2020a). For this purpose, kernel density estimation (KDE) was applied using the software PAST, version 4.03 (Hammer *et al.*, 2001). The KDE was implemented as a smoothing estimator of the histogram based on a Gaussian kernel, with the spatial smoothing parameter determined according to Silverman's rule of thumb (Silverman, 1986). The analysis was based on two-dimensional spatial data, incorporating the number of occurrence records at given geographic coordinates (longitude and latitude).

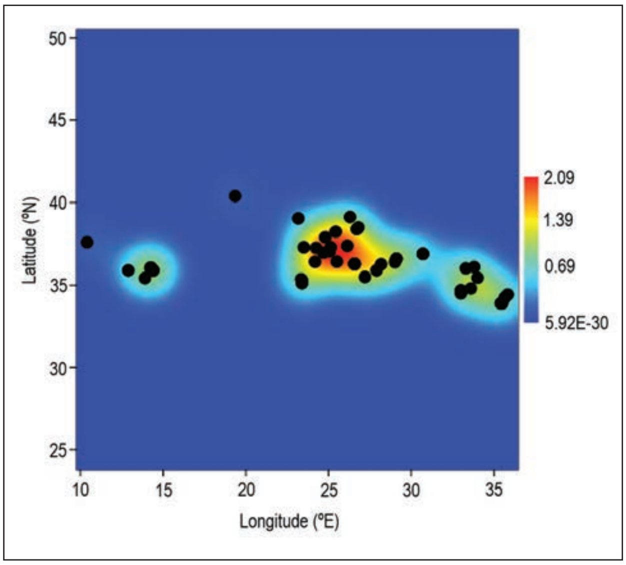

Fig. 3. Kernel density estimation (KDE) showing the spatial distribution of *Odontaspis ferox* ***occurrence records based on published data. The legend on the right represents occurrence density based on latitude and longitude records.***
Sl. 3: Ocena gostote jedra (KDE), ki prikazuje prostorsko razširjenost zapisov o pojavljanju vrste *Odontaspis ferox* ***na podlagi objavljenih virov. Legenda na desni prikazuje gostoto pojavljanja glede na podatke o zemljepisni širini in dolžini.***

Temporal trends in annual occurrence records were assessed using both the Mann–Kendall trend test and linear regression analysis, following contemporary approaches for the analysis of ecological time-series data (Warton, 2022). Differences in the distribution of individual records among geographical subareas across years were tested using a chi-square test of independence (Warton, 2022). Differences in the number of recorded individuals among geographical subareas and countries were assessed using the Kruskal–Wallis H test, followed by pairwise Mann–Whitney U tests where appropriate, as the data did not meet assumptions of normality (Warton, 2022). All statistical analyses were performed using PAST software, version 4.03 (Hammer *et al.*, 2001). Statistical significance was assessed at a significance level of $p = 0.05$ (Parab & Bhalerao, 2010). Raw data will be made available on reasonable request.

RESULTS AND DISCUSSION

Spatial occurrence of *Odontaspis ferox*

Following the methodologies described above, a total of 46 occurrence records from the period 1964–2025 were included in the present review (Tab. 1). The distribution of *Odontaspis ferox* in the Mediterranean Sea based on published records is illustrated in the map (Fig. 1). The records were unevenly distributed across the basin, with a strong concentration in the Aegean Sea (GSA 22), which accounted for 50% of all records (n = 23) (Fig. 2). This spatial clustering was further supported by kernel density estimation (KDE) analysis, indicating a high concentration of occurrences between 25–30°E longitude and 35–40°N latitude (Fig. 3). GSA 22 differed significantly from all other GSAs (Kruskal–Wallis test: $p < 0.05$), as confirmed by pairwise comparisons with the other subareas (Mann–Whitney U test: $p < 0.05$).

Of the total records, 45.65% were reported from Greek waters, followed by Türkiye with 19.57% (Fig. 2). The distribution of occurrence records among countries also differed significantly (Kruskal–Wallis test: $p < 0.05$ for all countries). Pairwise comparisons using the Mann–Whitney U test showed significant differences between Greece and all other countries except Türkiye ($p < 0.05$), and between Türkiye and all other countries except Greece ($p < 0.05$), whereas no significant difference was detected between Greece and Türkiye ($p > 0.05$; $p = 0.15$).

Temporal occurrence of *Odontaspis ferox*

The temporal distribution of occurrence records among geographical subareas also displayed significant differences (chi-square test: $p < 0.05$; $p = 0.019$). The Mann–Kendall trend test revealed a statistically significant increasing trend in the annual number of records across the entire study area ($p < 0.001$; Fig. 4). Results of the Mann–Kendall trend analysis for individual countries are presented in Table 2. Although statistically significant increasing trends were detected for Greece ($p < 0.001$) and Türkiye ($p < 0.008$), the trend observed for GSA 22 did not reach statistical significance ($p > 0.05$) (Tab. 2).

The present study provides an updated overview of the distribution of *O. ferox* in the Mediterranean Sea. To address this objective, spatial and temporal analyses of occurrence records were conducted, based on density and trend analyses of published data. The compiled records suggest that the eastern Mediterranean Sea, and especially the Aegean Sea within GSAs 23–27, is gaining increasing importance for the persistence of the species, emphasizing the regional significance of the eastern Mediterranean within the global distribution range of *O. ferox*.

The conservation of sharks and their relatives (Chondrichthyes) has become an increasing concern, as nearly one-third of species are currently threatened with extinction (Dulvy *et al.*, 2021). Historically, lethal sampling was considered the most effective method for obtaining life-history information (Walker, 1998). However, growing awareness of the ecological importance of sharks, alongside a shift in public perception of large apex predators from fearsome animals to charismatic megafauna (Mazzoldi *et al.*, 2019), has led to a widespread adoption of non- or minimally invasive research methods

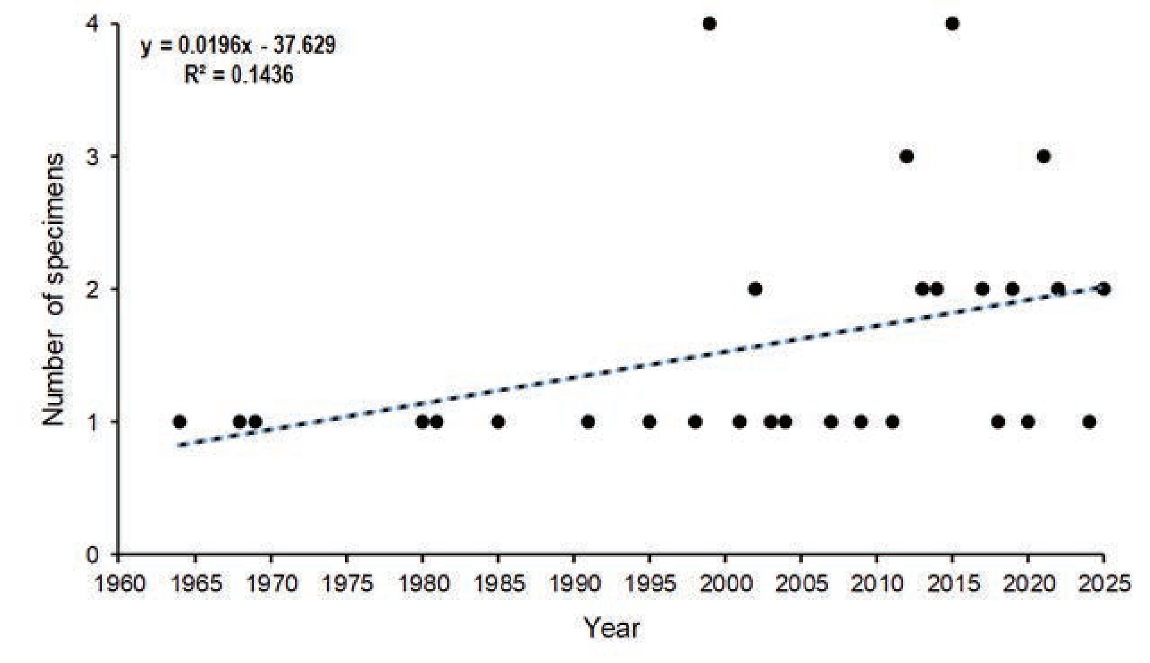

Fig. 4. Annual trend in occurrence records of *Odontaspis ferox* ***(1964–2025).***
Sl. 4: Letni trend zapisov o pojavljanju vrste *Odontaspis ferox* ***v obdobju 1964–2025.***

(Heupel & Simpfendorfer, 2010). Visual techniques, including photography and videography, now allow researchers to study population composition, abundance, residency, movement, demography, and social behavior without harming individuals. In the Mediterranean, such approaches have been successfully applied to investigate the behavior of endangered batoids, identify aggregation sites, and assess trophic interactions, thereby demonstrating their effectiveness in ecological and conservation research (Kabasakal, 2009; Bilgili & Kabasakal, 2023; Tiralongo *et al.*, 2025).

Citizen science (CS) programs have further expanded the reach of these non-invasive approaches, enabling broader data collection while actively engaging the public in conservation efforts (Gibson *et al.*, 2019; Ferretti *et al.*, 2025). CS initiatives are particularly valuable for documenting rare or elusive Mediterranean sharks that are difficult to detect through conventional scientific surveys (Bargnesi *et al.*, 2020b). In addition, the growing involvement of CS in natural resource management allows the expansion of research effort at relatively low cost while fostering meaningful public engagement (Gibson *et al.*, 2019; Ferretti *et al.*, 2025). When carefully coordinated and combined with non-invasive visual methods, CS contributes significantly to long-term monitoring programs, improving both the spatial and temporal coverage of population assessments and supporting evidence-based management of threatened elasmobranch species.

Recent studies clearly demonstrate that CS has contributed to a marked increase in the number of records of *O. ferox* in the Mediterranean Sea (Kabasakal *et al.*, 2024; Pyloridou *et al.*, 2025). Notably, 61.5% (n = 16) of the most recent unpublished records of the species originated from CS efforts (Pyloridou *et al.*, 2025). Nevertheless, as emphasized by Gibson *et al.* (2019), CS-derived data are sometimes viewed with caution due to potential limitations in data collection rigor and validation procedures. This concern was also highlighted by Soldo (2026) in a recent study addressing a debated record of a lamnid shark from the Adriatic Sea, in which the author recommended that CS-derived records of rare elasmobranchs should be supported by high-quality photographic documentation of diagnostic features, allowing independent evaluation by taxonomic experts.

Since the comprehensive review by Fergusson *et al.* (2008), knowledge of the contemporary occurrence and distribution of *O. ferox* in the Mediterranean Sea and adjacent waters has increased markedly. Owing to the efforts of several researchers in the eastern Mediterranean region, the number of records of *O. ferox* from the waters of Greece (Corsini-Foka, 2009; Zaferiaki *et al.*, 2019; Moutopoulos *et al.*, 2022; Pyloridou *et al.*, 2025), Türkiye (Kabasakal & Bayrı, 2019; Kabasakal & Bilecenoğlu, 2020; Kabasakal *et al.*, 2024), Lebanon (Bariche & Fricke, 2020), and Cyprus (Akbora *et al.*, 2019) has increased by 90.4%, 80%, 75%, and 33.3%, respectively. Comparable research efforts in several other geographical subareas (GSAs) of the Mediterranean Sea have also substantially improved understanding of the contemporary occurrence of *O. ferox* in the region (Ben Amor *et al.*, 2020; Soldo *et al.*, 2022; Shakman *et al.*, 2023).

Tab. 2. Results of the Mann–Kendall trend test for *Odontaspis ferox* ***occurrence records by country and geographical subarea (GSA). S: Mann–Kendall test statistic indicating the direction of a monotonic trend; Z: standardized test statistic used to assess the significance of the trend; p: p-value; Y: yes; N: no.***

Tab. 2: Rezultati Mann–Kendallovega testa trenda za podatke o pojavljanju vrste *Odontaspis ferox* ***po državah in geografskih podobmočjih (GSA). S: statistika Mann–Kendallovega testa, ki nakazuje smer monotonega trenda; Z: standardizirana testna statistika, uporabljena za ocenjevanje značilnosti trenda; p: p-vrednost; Y: da; N: ne.***

	S	**Z**	**P**	**Significant trend Y/N**
Italy	-26	-0.498	0.618	N
Malta	48	0.673	0.501	N
Tunisia	51	1.397	0.162	N
Albania	53	1.453	0.146	N
Greece	405	3.294	**0.001**	**Y**
Türkiye	267	2.654	**0.008**	**Y**
Cyprus	55	1.076	0.282	N
Lebanon	20	0.272	0.785	N
GSA13	19	0.975	0.330	N
GSA15	-44	-1.225	0.221	N
GSA16	-40	-1.518	0.129	N
GSA18	21	1.083	0.279	N
GSA22	45	0.798	0.425	N
GSA23	43	1.358	0.175	N
GSA24	63	1.763	0.078	N
GSA25	1	0	1	N
GSA27	-32	-0.883	0.377	N

A point that requires particular clarification concerns the exclusion of some records of *O. ferox* from Libyan and Syrian waters from the present assessment. According to Shakman *et al*. (2023), the smalltooth sandtiger shark is among the eight elasmobranch species reported as bycatch in the Libyan tuna longline fishery; however, the national inventory of chondrichthyan species occurring off the Libyan coast does not provide precise or even approximate locality data for the captured specimens. Similarly, although two specimens of *O. ferox* have recently been reported from Syrian waters (OBIS, 2024; cited in Pyloridou *et al*., 2025), these records could not be included in the present assessment due to the absence of locality information. Since kernel density estimation (KDE) strictly requires geographic coordinates and weighted numbers of specimens associated with specific localities, records from Libyan and Syrian waters had to be excluded. Nevertheless, it should be noted that, should the locality data of *O. ferox* individuals potentially captured in these regions become available in the future, the existing KDE estimates could be improved by incorporating a broader geographical coverage.

Despite these limitations, when compared with the 14 *O. ferox* individuals reported from the Mediterranean Sea in the compilation by Fergusson *et al*. (2008), the increase to 46 individuals in the present assessment represents an important achievement that is a combined outcome of citizen science, effective use of large datasets, systematic screening of unpublished records, and rigorous taxonomic evaluation. The rapid development of digital technologies, along with the ability to share an observation with the public almost instantaneously and for such information to be noticed and transformed into scientifically valid data by researchers, has gained undeniable momentum. Specifically, SharkPulse, which aims to source large volumes of shark images shared online and transform them into occurrence records (Ferretti *et al*., 2025), represents a revolutionary digital development in this field. However, the increase in *O. ferox* occurrence records facilitated by CS and digital tools should be viewed not merely as an endorsement of these methods, but rather as evidence of their effective application. At the same time, a rigorous screening process must be applied when evaluating shark observation records obtained from social media platforms or citizen science (Mancusi *et al*., 2020). The MEDLEM project, which has been conducted to date to record large cartilaginous fish species throughout the Mediterranean, emphasizes that every new record obtained from these sources must undergo a data quality control process, in which unverified records are removed and duplicate records are eliminated (Mancusi *et al*., 2020). The details of the general algorithm used in the MEDLEM study to generate robust datasets on the distribution of large cartilaginous fish from all data obtained via social media, citizen science, and systematic scientific sampling are provided in full in Mancusi *et al*. (2020).

An examination of the global distribution of *O. ferox* shows that its sporadic records are frequently associated with insular shelves (Ebert *et al*., 2021). Globally, comparable concentrations of records occur only in a limited number of regions, such as the Tasman Sea (Fergusson *et al*., 2008). Topographic features, including seamounts, islands, and the outer margins of continental shelves, appear to be closely associated with the occurrence of *O. ferox* (Ebert *et al*., 2021). A relevant example of such topographic complexity is the Finike Basin and Anaximander Mountain complex, located in the westernmost sector of the northern Levantine Sea (GSA 24) (GFCM, 2018). The major topographic framework of the complex comprises three principal positive morphological features—two ridges and one seamount—situated at the junction of the Hellenic and Cypriot arcs, east of the ~4000 m deep Rhodes Basin (Otero & Mytilineou, 2022). The Anaximander Ridge is an approximately 80 km long, east–west-oriented narrow ridge bounded by steep slopes, rising from depths exceeding 2,000 m to a summit depth of about 1,102 m. The Anaximenes Ridge forms a concave, southwest–northeast oriented structure with a base depth exceeding 1,500 m and a summit depth of 678 m, whereas Anaxagoras Seamount, rising from an over 1,500 m deep seafloor, reaches a summit depth of 919 m (Otero & Mytilineou, 2022). Considering the presence of numerous islands, together with a complex submarine topography characterized by seamounts and ridges, and given that 50% of *O. ferox* records from the eastern Mediterranean originate from this area, the Aegean Sea can be considered one of the few globally important regions for the occurrence of this species. The steadily increasing number of records from the Aegean Sea further supports this interpretation. In addition, records from Mersin, together with those from nearby Cyprus, as well as from Syrian and Lebanese waters to the east, suggest the existence of another potential clustering area in the eastern Mediterranean. Taken together, these findings indicate that the marine region extending from the Aegean Sea to Lebanon may represent a regional hotspot for *O. ferox*, a pattern also supported by the spatial analyses presented in the present study.

In conclusion, *O. ferox* is a species of critical conservation concern in the Mediterranean Sea. Its K-selected life-history traits, including slow growth, late maturity, and low reproductive output, severely limit the capacity of depleted populations to recover rapidly, rendering the species particularly sensitive to additional sources of mortality (Pollard *et al.*, 2016). In line with its conservation status, *O. ferox* is legally protected in Türkiye; however, incidental capture as bycatch remains the principal threat to the species throughout the Mediterranean (Carpentieri *et al.*, 2021). Although the release of accidentally captured individuals without harm is formally required, such practices are not always implemented effectively in real fishing operations, and mortality associated with handling, delayed release, or inadequate onboard procedures may substantially undermine the intended benefits of legal protection. Under these circumstances, each reliably documented occurrence, particularly those supported by photographic evidence, represents a valuable contribution to understanding the species' distribution and conservation status.

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RAZŠIRJENOST VRSTE *ODONTASPIS FEROX* V SREDOZEMSKEM MORJU: SPOZNANJA NA PODLAGI PROSTORSKIH IN ČASOVNIH ANALIZ

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POVZETEK

Avtor ponuja posodobljen pregled pojavljanja in razširjenosti morskega psa vrste Odontaspis ferox *v Sredozemskem morju, ki temelji na 46 podatkih iz obdobja med letoma 1964 in 2025. Ugotovil je, da so podatki o pojavljanju neenakomerno porazdeljeni po celotnem bazenu, z izrazito gostoto v Egejskem morju (GSA 22), kjer je zabeležena skoraj polovica vseh zapisov o pojavljanju. Metoda ocene gostote jedra je dodatno potrdila to prostorsko zgostitev in izpostavila vzhodno Sredozemlje. Časovna analiza je razkrila znatno povečanje letnega števila zapisov o pojavljanju, kar odraža tako okrepljena raziskovalna prizadevanja kot tudi vse večji prispevek ljubiteljske znanosti, ki jo omogočajo digitalne tehnologije. Kljub temu da določenih zapisov iz libijskega in sirskega morja zaradi odsotnosti natančnih lokacijskih podatkov ni bilo mogoče zaobjeti, ta zbirka pomeni bistven prirast glede na predhodne ocene.*

Ključne besede: drobnozobi morski vol, razširjenost, vroča točka, ocena gostote jedra, vzhodno Sredozemlje

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IS THE GULF OF TRIESTE A POTENTIAL NURSERY AREA FOR CERTAIN ELASMOBRANCH SPECIES?

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ABSTRACT

This study aimed to determine whether the Gulf of Trieste meets the criteria for a nursery area as defined by different sources, primarily Heupel et al. *(2007). The analysis was based on elasmobranch specimens from the collection of the Marine Biology Station Piran (National Institute of Biology, Slovenia), comprising five species (*Mustelus mustelus, M. punctulatus, Torpedo marmorata, Raja asterias, *and* Aetomylaeus bovinus*) caught as bycatch over a 24-year period. Four of the five species (excluding* A. bovinus*) fulfilled all three criteria. According to the data analyzed, the Gulf of Trieste could be considered a communal juvenile nursery area for the assessed species. In addition, records of juveniles belonging to other elasmobranch species reported during the study period in the area suggest the potential importance of this area as a nursery ground for other species as well.*

Key words: elasmobranchs, parturition, nursery area criteria, abiotic conditions, bycatch, northern Adriatic

PUÒ IL GOLFO DI TRIESTE VENIR CONSIDERATO UN'AREA DI NURSERY PER ALCUNE SPECIE DI ELASMOBRANCHI?

SINTESI

Lo studio ha l'obiettivo di verificare se il Golfo di Trieste soddisfi i criteri per essere definito un'area di nursery secondo diverse fonti, in particolare secondo Heupel et al. *(2007). L'analisi si è basata sugli esemplari di elasmobranchi conservati nella collezione della Stazione di biologia marina di Pirano (Istituto nazionale di biologia, Slovenia), comprendente cinque specie (*Mustelus mustelus, M. punctulatus, Torpedo marmorata, Raja asterias e Aetomylaeus bovinus*) catturate come catture accessorie nell'arco di 24 anni. Quattro delle cinque specie (esclusa* A. bovinus*) hanno soddisfatto tutti e tre i criteri. Sulla base dei dati analizzati, il Golfo di Trieste potrebbe essere considerato un'area di nursery giovanile comune per le specie valutate. Le segnalazioni di individui giovanili di altre specie di elasmobranchi registrate nell'area suggeriscono l'importanza potenziale del Golfo come nursery anche per altre specie.*

Parole chiave: elasmobranchi, parto, criteri di area di nursery, condizioni abiotiche, catture accessorie, Adriatico settentrionale

INTRODUCTION

Most elasmobranch species occupy high trophic levels in marine ecosystems and play a major role in their structure and function, which means that their removal would likely be detrimental to these ecosystems (Pough & Janis, 2019). They display K-selected life-history traits, which include slow growth rates, long lifespans, late maturity, long gestation periods, and few offspring (Dulvy *et al.,* 2014). Along with a general tendency toward age and sex segregation, these traits make them especially vulnerable to human impacts, as many species require more than one suitable habitat for different segments of the population (*i.e.*, juveniles and adults, males and females) (Muñoz-Chapuli, 1984; Bradai *et al*.; 2005; Pough & Janis, 2019). In the Mediterranean Sea, volumes and species composition of elasmobranchs captured as bycatch are poorly documented, with available data often too inconsistent to be incorporated in national and international statistics (Dulvy *et al*., 2014) and the taxonomic resolution of catch statistics remaining poor (Cashion *et al*., 2019). Recently, the Important Shark and Ray Area (ISRA) identification process in the Mediterranean Sea has classified 2 ISRAs in the northern Adriatic, namely, the western Vir Sea (Croatia), important for angel sharks (*Squatina squatina*), and Cervia–Marina di Ravenna (Italy), important for sandbar sharks (*Carcharhinus plumbeus*) (ISRA, 2025). Additionally, the entire northwestern Adriatic has been classified as an ISRA for threatened species such as the spiny dogfish (*Squalus acanthias*), and as a reproductive area for the common smooth-hound (*Mustelus mustelus*) (ISRA, 2025). The Gulf of Trieste and the broader northern Adriatic have previously been suggested as nursery areas for certain elasmobranch species by Lipej *et al*. (2008; 2024; Fig. 1), but they have never been directly evaluated as such.

Beck *et al.* (2009) define a nursery area as an environment in which juveniles of a certain species occur at higher densities, experience lower predation risk, or exhibit faster growth rates than in other areas (Tab. 2). Also, the species using an area as a nursery are expected to enter the area as neonates, accumulate biomass, and then move offshore. However, some of these criteria are vague and difficult to assess, even with modern technology (Heupel *et al.,* 2007). Heupel *et al.* (2007) proposed an alternative set of criteria, according to which an area can be defined as an elasmobranch nursery if: i) newborn or young-of-the-year individuals are encountered there more frequently than in other areas; ii) newborn or young-of-the-year individuals tend to remain in or return to for extended periods; iii) the area or habitat is repeatedly used across years (Tab. 2). Martins *et al.* (2018) adopted the criteria proposed by Heupel *et al.* (2007) for viviparous species, but added criteria for discriminating between nursery areas of ovoviviparous and oviparous species, and distinguished juvenile habitats (secondary nursery areas) from nursery habitats (primary nursery areas), as first introduced by Bass (1978). Primary and secondary nursery areas may overlap, but not necessarily. Distinguishing between them is important in areas where many species co-occur, given that cannibalism is common among some elasmobranch groups. In these cases, juvenile aggregation areas that are spatially separated from the adults may in fact function as nursery areas, with the adult–juvenile segregation serving as an important qualifying

Fig. 1: Juvenile and newborn specimens of the Mediterranean starry ray (*Raja asterias*) and adult and newborn specimens of the marbled electric ray (*Torpedo marmorata*) from the Gulf of Trieste. (Photos by Jernej Uhan and Domen Trkov, respectively)

Sl. 1: Mladostni osebki in novorojenčki zvezdaste raže (*Raja asterias*) ter odrasli osebki in novorojenčki marmoriranega električnega skata (*Torpedo marmorata*) iz Tržaškega zaliva. (Avtorja fotografij: J. Uhan in D. Trkov).

characteristic (Heupel *et al.,* 2007; Martins *et al*., 2018). There have also been records of different species using the same area as a nursery, called a communal nursery, where juveniles of multiple species co-occur while adults are mostly absent (Rosa *et al*., 2023). However, in such nurseries, juveniles face a trade-off between lower predation risk and increased competition, both with conspecifics and juveniles of other species. This effect may be reduced through resource partitioning, provided these are sufficient within the nursery area (Rosa *et al*., 2023). The purpose of this study was to examine the available data on elasmobranch species in the Gulf of Trieste and determine whether sufficient evidence exists to classify the area as an elasmobranch nursery.

MATERIAL AND METHODS

Study area

The Gulf of Trieste is the northernmost part of the Adriatic Sea, shared by Italy, Slovenia, and Croatia (Fig. 2). The Istrian peninsula partially closes it off to the south, creating a relatively isolated area (Malačič & Petelin, 2009). Covering around 600 km^2, the gulf has an average depth of 18.7 m and a maximum depth of 25 m (DEIMS-SDR, 2025). Apart from several flat islets at the entrance to the Marano–Grado lagoon, no islands occur within the gulf. Its main freshwater input (Fig. 2) is provided by the Isonzo River (Monti *et al*., 2012). Although tidal amplitudes in the Gulf of Trieste are among the largest in the Adriatic Sea, they rarely exceed 1 m (Malačič & Petelin, 2009). The southeastern coast, extending from Miramare to Muggia, has been extensively modified by human activity and artificial structures such as piers and harbor facilities (Monti *et al*., 2012). The majority of the Slovenian part of the gulf is characterized by sedimentary bottom (mud, muddy sand, and sand) (UNEP, 2021). The remaining rocky coastal areas include sandstone habitat types colonized by algal vegetation, whereas sheltered bays support seagrass meadows. Offshore, the soft-bottom seabed is interspersed with thousands of biogenic outcrops formed by calcareous organisms growing on various hard substrates (Falace *et al*., 2024). The northern Adriatic is one of the

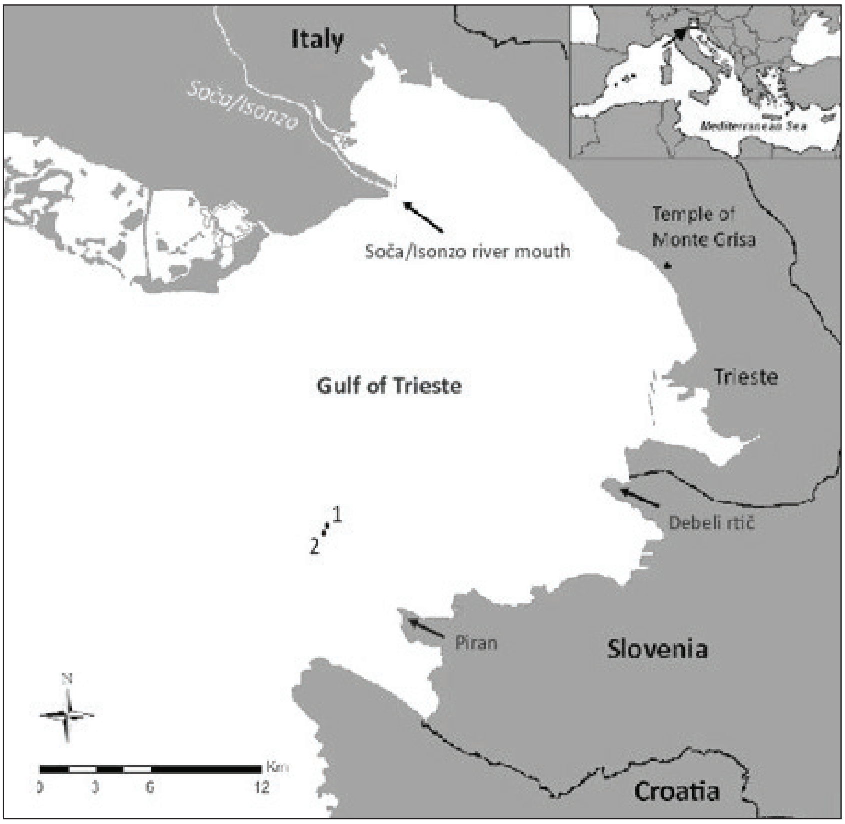

Fig. 2: Map of the Gulf of Trieste.
Sl. 2: Zemljevid obravnavanega območja Tržaškega zaliva.

regions with the highest permanent production in the Mediterranean Sea, where mesozooplankton biomass exhibits a much broader range than elsewhere (Conversi *et al.*, 2009).

Species analyzed

A total of 549 specimens belonging to 5 species were assessed, including 2 shark species and 3 batoid species (Tab. 1): the common smooth-hound (*M. mustelus*), the blackspotted smooth-hound (*M. punctulatus*), the marbled electric ray (*Torpedo marmorata*), the Mediterranean starry ray (*Raja asterias*), and the bull ray (*Aetomylaeus bovinus*). All specimens included in the analysis were caught as bycatch in the Gulf of Trieste between 2000 and 2024 and were subsequently handed over to researchers at the Marine Biology Station (National Institute of Biology) in Piran. Specimens were sexed based on the presence or absence of secondary sexual characters (*i.e.*, claspers). Sexual maturity and age were determined using indicators such as clasper calcification, umbilical scars, and body size compared to known size at maturity. For specimens without direct age/maturity data but for which biometric data were available, maturity was estimated as newborn, juvenile, or adult based on publicly available literature (CIESM, 2025; FishBase, 2025). For each specimen, we calculated Fulton's condition factor using the formula (Fulton, 1902): K = (W/L^3) x 100, where *K* is Fulton's condition factor, *W* is the weight of the fish (g), and *L* is the length (typically total length in cm). We then compared these values to species-specific condition factors from previous studies conducted in the Mediterranean Sea. Condition factors serve as indicators of fish welfare and population health, as they reflect environmental quality and suitability, including water quality and food availability. They also provide information on the interaction between biotic and abiotic factors influencing the physiological condition of different species (Ragheb, 2023).

The occurrence of the species in the Adriatic Sea was also included in the analysis. Five occurrence classes were defined by Soldo & Lipej (2022): rare – when species is recorded after a long period of time (decades); occasional – recorded every few years; common – with several single records on a yearly basis; abundant – multiple records in catches or sighted every year; questionable/not confirmed – when a record needs confirmation. All five species included in this study have been reported to favor shallow coastal waters along the continental shelf, characterized by high food availability, as reproductive and nursery habitats (Serena & Relini, 2006; Consalvo *et al.*, 2007; Enajjar *et al.*, 2015; Catalano *et al.*, 2021); therefore, the Gulf of Trieste was considered a strong candidate for a potential nursery area.

Criteria for nursery areas

Among several nursery area definitions, we decided to use the criteria defined by Heupel *et al.* (2007) (Tab. 2), as they can be applied to areas such as the northern Adriatic, where bycatch and sighting reports are scant and tracking data for juveniles or adults are unavailable. The biotic and abiotic conditions of the Gulf of Trieste were also compared to the environmental preferences of each of the five species through a systematic literature review. Analyzing these parameters alongside comparable data from the rest of the northern Adriatic and the Mediterranean Sea, we assessed whether the Gulf of Trieste can be considered a nursery ground for certain elasmobranch species found in the Adriatic Sea, based on the three nursery area criteria described by Heupel *et al.* (2007).

Tab. 1: Species analyzed, occurrence status in the Adriatic, total number of specimens caught, number of specimens with available biometric data (males:females), and total length (TL) at maturity for each sex.
Tab. 1: Analizirane vrste, njihov status v Jadranu, število ujetih osebkov, biometrični podatki (samci: samice) in celotna dolžina (TL) ob spolni zrelosti za vsak spol.

Latin name	Common name	Occurrence in the Adriatic Sea (Soldo & Lipej, 2022)	No. of specimens caught (2000-2024)	No. of male : female specimens with biometric data	Total length at maturity for males : females in cm	Reproductive Period / parturition
Mustelus mustelus	common smooth-hound	abundant	138	13 : 20	70–80 cm : 70–80 (Lipej *et al.*, 2011; FishBase 2025)	late spring (Saïdi *et al.*, 2008; Ozcan & Başusta, 2018; Boscolo Palo *et al.*, 2022)
Mustelus punctulatus	blackspotted smooth-hound	common	175	111 : 56	90 cm : 100 (Lipej *et al.*, 2011; FishBase, 2025)	mid-May to early June (Saïdi *et al.*, 2009; Boscolo Palo *et al.*, 2022)
Torpedo marmorata	marbled electric ray	common	74	47 : 27	24.1 : 26.1 (Bajt *et al.*, 2024)	May, August, September–February (Capapé, 1979; Consalvo *et al.*, 2007; Chatzispyrou *et al.*, 2021)
Raja asterias	Mediterranean starry ray	common	127	88 : 22	45–54 : 56.1–60 (Sviben *et al.*, 2019; CIESM, 2025)	summer to early autumn (Stehmann & Bürkel, 1984; Serena & Relini, 2006)
Aetomylaeus bovinus	bull ray	rare	37	20 : 17	80–95 : 90–100 (CIESM, 2025)	late spring and summer (Michael, 1993)

Tab. 2: Summary of nursery area definitions and criteria according to different authors.
Tab. 2: Pregled definicij in meril za območja odraščanja (ang. nursery areas) po različnih avtorjih.

Publication	**Nursery Area Criteria**
Heupel *et al.*, 2007	(1) Newborn/young-of-the year individuals are more commonly encountered there than in other areas. (2) Newborn/young-of-the-year individuals have a tendency to remain or return for extended periods. (3) Newborn/young-of-the-year individuals repeatedly use the area or habitat across years.
Beck *et al.,* 2009	> an area in which juveniles occur at higher densities, > they avoid predation more successfully, > they grow faster compared to a different habitat, > the species moves into the area as larvae/neonates, accumulate biomass, and then move offshore, > contribution per unit area to the production of individuals that recruit to adult populations is greater, on average, than production from other habitats in which juveniles occur, from any combination of four factors, the ideal being an area having all 4 factors at high values: (1) density (2) growth (3) survival of juveniles (4) movement to habitats inhabited by adults
Martins *et al.*, 2018	> **Egg case nursery/Primary nursery area/For oviparous species:** (1) high densities of eggs and egg cases in contact with the benthos or permanent structures (2) area must be used as an egg-laying area over multiple years by adults (3) newborns should leave the area promptly after hatching > **Juvenile nursery area/Secondary nursery area**: (1) should have a high abundance of neonates and juveniles, (2) may or may not be distinct from the egg case nursery (3) should strongly contribute to population recruitment > **Nursery area for viviparous species (Heupel *et al.*, 2007)**: (1) Newborn/young-of-the-year individuals are more commonly encountered there than in other areas. (2) Newborn/young-of-the-year individuals have a tendency to remain or return for extended periods. (3) Newborn/young-of-the-year individuals repeatedly use the area or habitat across years.

RESULTS AND DISCUSSION

Smooth-hound, *Mustelus mustelus* (Linnaeus, 1758)

A total of 138 *M. mustelus* specimens were caught as bycatch during the study period and included in the analysis. All individuals examined were juveniles, and no newborns with postnatal scars were reported. Juvenile females were more frequent than juvenile males, with a female-to-male ratio of 60:40 (Fig. 3). All specimens were caught over a 10-year span, specifically in September and October between 2011 and 2021. The average Fulton's condition factor across all specimens was 0.0032 (Tab. 3) with a standard error of ±0.000221, and females had a slightly higher mean than males (Tab. 4). Since all specimens were juveniles, no comparisons of condition factor between juveniles and adults could be made.

Blackspotted smooth-hound, *Mustelus punctulatus* (Risso, 1827)

Of the 175 *M. punctulatus* specimens included in the analysis, males were more frequent than females, with a sex ratio of 66:33 (Fig. 3). While no newborns were recorded, juvenile specimens of both sexes accounted for 65.3% of all specimens. Both juvenile and adult specimens were reported from September to November, as well as in January and from April to June. The specimens included in this study were caught in 2002, 2003, 2011, and 2014, with juveniles reported in each of those years. The average Fulton's condition factor was 0.0031 (Tab. 3) with a standard error of ±0.000302, and males had a higher average than females (Tab. 4). Since biometric data were only available for juvenile specimens, no comparisons of Fulton's condition factors could be made between juvenile and adult specimens.

Marbled electric ray, *Torpedo marmorata* (Risso, 1810)

A total of 74 *T. marmorata* specimens were analyzed. The adult sex ration was almost 50:50, whereas juvenile males were more frequent than juvenile females, with a 3:1 ratio (Fig. 3). Three newborn males were recorded, and together with the other juveniles, they accounted for 55.4% of all specimens caught. *T. marmorata* was the most frequently caught species on a monthly basis. From September to March and in May, both adult and juvenile specimens were caught, with one newborn specimen caught in January and two in

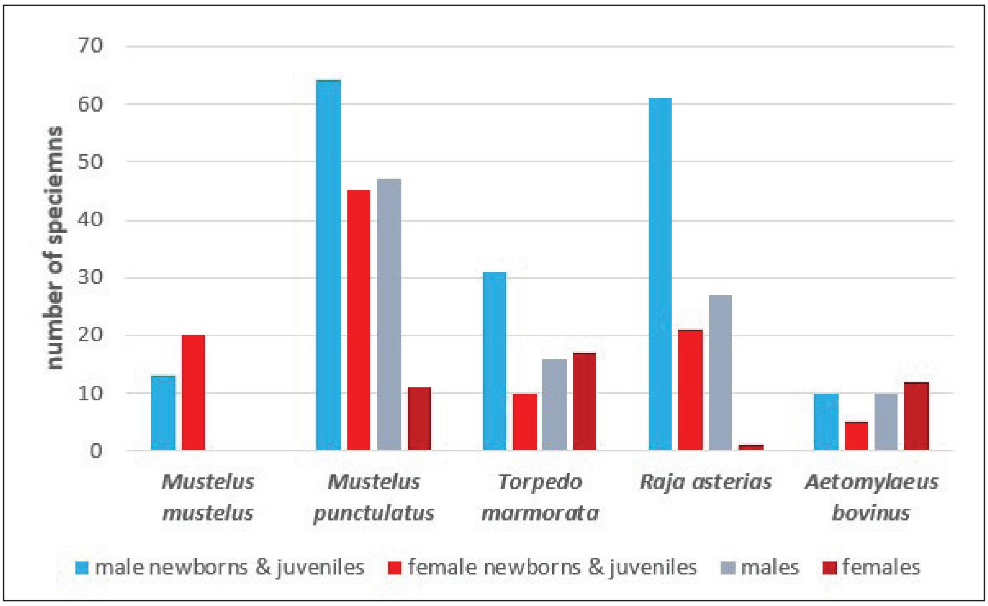

Fig. 3: Maturity and sex distribution in adults and juveniles of the five species included in this study. Males (grey) and females (dark red) refer to adult individuals.
Sl. 3: Porazdelitev zrelosti in spola pri odraslih osebkih in mladostnih primerkih petih vrst, vključenih v to raziskavo. Samci (sivo) in samice (temno rdeče) se nanašajo na odrasle osebke.

Tab. 3: Fulton's condition factor values for the five species included in this study compared with values reported from other Mediterranean studies.
Tab. 3: Vrednosti Fultonovega kondicijskega faktorja za pet vrst, vključenih v to raziskavo, v primerjavi z vrednostmi iz drugih sredozemskih študij.

Species	**Range**	**Average**	**Study**
M. mustelus	0.0028–0.0036	0.032	**this study**
	0.002–0.003	/	Filiz & Mater, 2002
	0.003–0.004	/	Ismen et al., 2007
	/	0.004	Ozcan & Başusta, 2018
	0.003–0.01	/	Colombelli & Bonanomi, 2022
M. punctulatus	0.026–0.036	0.0031	**this study**
	/	0.003	Colombelli & Bonanomi, 2022
T. marmorata	0.0119–0.0870	0.0285	**this study**
	0.022–0.027	/	Filiz & Mater, 2002
	0.019–0.023	/	Ismen *et al.*, 2007
	/	0.025	Duman & Başusta, 2013
R. asterias	0.0007–0.0068	0.0055	**this study**
	/	0.007	Karakulak et al., 2006
	/	0.007	Ferrà et al., 2016
A. bovinus	0.0022–0.0141	0.0052	**this study**
	0.012–0.022	/	Başusta *et al.*, 2012
	/	0.004	Tsikliras & Dimarchopoulou, 2021
	0.014-0.021	/	Colombelli & Bonanomi, 2022

Tab. 4: Fulton's condition factor values for the five species included in this study by sex.
Tab. 4: Vrednosti Fultonovega kondicijskega faktorja po spolu za pet vrst, vključenih v to raziskavo.

Species	Males		Females	
	Range	Average	Range	Average
M. mustelus	0.0028–0.0035	0.0031	0.0028–0.0036	0.0032
M. punctulatus	0.0026–0.0036	0.0032	0.0028–0.0034	0.0030
T. marmorata	0.0119–0.0870	0.0255	0.0168–0.0795	0.0337
R. asterias	0.0043–0.0065	0.0055	0.0007–0.0068	0.0057
A. bovinus	0.0022–0.0050	0.0031	0.0026–0.0141	0.0059

Tab. 5: Fulton's condition factor values for the five species included in this study by maturity stage.
Tab. 5: Vrednosti Fultonovega kondicijskega faktorja po stopnjah zrelosti za pet vrst, vključenih v to raziskavo.

Species	Newborns		Juveniles		Adults	
	Range	Average	Range	Average	Range	Average
M. mustelus	/	/	0.0028–0.0036	0.0032	/	/
M. punctulatus	/	/	0.0026–0.0036	0.0031	/	/
T. marmorata	0.0204–0.0870	0.0380	0.0119–0.0795	0.0305	0.0168–0.0738	0.0252
R. asterias	/	/	0.0007–0.0068	0.0056	0.0048–0.0066	0.0055
A. bovinus	/	/	0.0022–0.0040	0.0030	0.0026–0.0141	0.0056

December. In April and August, only adult specimens were caught, while no specimens were caught in June or July. The *T. marmorata* specimens analyzed in this study were caught between 2011 and 2014, with both juveniles and adults reported in each year. The average Fulton's condition factor was 0.0285 (Tab. 3) with a standard error of ±0.017578. Females had a higher average than males (Tab. 4), and newborns and juveniles had a higher average than adults (Tab. 5).

Mediterranean starry ray, *Raja asterias* (Delaroche, 1809)

Male *R. asterias* juveniles and adults outnumbered females, with a combined sex ratio of 4:1 (Fig. 3). No newborns were recorded; however, juveniles of both sexes accounted for 74.6% of all individuals. Specimens were caught in April and from July to December during the period 2011–2016, with juveniles recorded in each year. The average Fulton's condition factor was 0.0055 (Tab. 3) with a standard error of ±0.000908. Females had a higher average than males (Tab. 4), and juveniles had a higher average than adults (Tab. 5).

Bull ray, *Aetomylaeus bovinus* (Geoffroy Saint-Hilaire, 1817)

While *A. bovinus* was the only species in which juvenile specimens were less abundant than adults, juveniles still accounted for 40.54% of all caught individuals. Adult males and females occurred at an almost equal 1:1 frequency, while juvenile males outnumbered females by 2:1 (Fig. 3). Four male embryos were found inside pregnant females; however, these were not included in the analysis. Both adult and juvenile specimens were reported from August to September 2005. The average Fulton's condition factor was 0.0052 (Tab. 3) with a standard error of ±0.003550. Females had a higher average than males (Tab. 4), and adults had a higher average than juveniles (Tab. 5).

Fulfillment of the three criteria defining nursery areas for the studied species

The first criterion – that juveniles are more frequently encountered in the area compared to other areas – was met by four of the five species. While catches of juveniles and adults of the examined species have been sporadically reported in the northern Adriatic, mostly along the Croatian coast, no solid nursery areas for any of the examined species have been confirmed yet. In the southern Adriatic, a nursery area for *R. asterias* has been proposed along the Albanian coast (Bakiu & Kule, 2024), however, it is unlikely that the *R. asterias* specimens caught in the northern Adriatic originated there.

For *M. mustelus*, all individuals recorded in the Gulf of Trieste during the study period were juveniles; therefore, the first criterion is considered fulfilled for this species. Given that no established nursery area for *M. mustelus* has been identified nearby and that the entire northwestern Adriatic has been classified as an ISRA important for the reproduction of this species (ISRA, 2025), it is possible that the Gulf of Trieste – as a confined part of the wider northwestern Adriatic area – plays an important role in its reproduction.

Juveniles also accounted for 65.3% of all *M. punctulatus* specimens, 55.4% of *T. marmorata* specimens, and 74.6% *of R. asterias* specimens; therefore, the first criterion is considered fulfilled for these species as well. In the Mediterranean, the closest suggested nursery area for *M. punctulatus* is in the Gulf of Gabes, southern Tunisia (Enajjar *et al.*, 2015), while for *R. asterias*, a nursery area has been identified within a restricted coastal zone of the southern Ligurian and northern Tyrrhenian Seas (Serena & Relini, 2006); therefore, the high proportion of juveniles of these two species recorded in the Gulf of Trieste is unlikely the result of a spillover from nearby nursery areas. For *T. marmorata*, both juvenile and adult specimens were recorded during the same period, suggesting that the species uses the Gulf of Trieste both as a reproductive habitat and a nursery area (pers. observation). This interpretation is further supported by observations from the shallow waters off the Sečovlje salina and within the salina channels, where numerous juvenile electric rays have been captured, sighted, photographed, and filmed (Kristina Gorišek, pers. comm.).

While juvenile specimens only accounted for 40.54% of all *A. bovinus* records, the occurrence of adults and pregnant females in the Gulf of Trieste during the same period suggests that reproduction may also take place in or near the area. Since *A. bovinus* is considered a thermophilic species, individuals may migrate seasonally into the Gulf of Trieste from more southern regions, potentially for foraging, given that all our records originate from the summer months. The closest potential nursery areas for *A. bovinus* in the Mediterranean are located along the southern Tunisian coast (Capapé and Quignard, 1975) and in the Amvrakikos Gulf in Greece (Ciprian *et al.*, 2026). The specimens recorded in the Gulf of Trieste may have originated from the latter area, given that the juvenile individuals for which TL/DW data were available were relatively large and close to the reported size at maturity for the species (87.5 cm for the male and 86.0 and 87.9 cm for the two females).

The second criterion – that juveniles remain in or return to the area for extended periods – was also fulfilled by four of the five species. Juvenile specimens were recorded over a period of several months, indicating that they are present not only following the reproductive period of adults, but also throughout the year. For all species except *A. bovinus*, both juvenile and adult specimens were recorded during periods corresponding to reproduction and immediately thereafter, also suggesting an increased abundance of juveniles shortly after the reproductive season.

Studies on the reproductive biology of *M. mustelus* place parturition in late spring (Saïdi *et al.,* 2008; Ozcan & Başusta, 2018; Boscolo Palo *et al.*, 2022). However, juveniles in the Gulf of Trieste were recorded in autumn, suggesting that they use the area independently of adult reproductive grounds, potentially as a secondary or juvenile nursery area. Accordingly, the second criterion can be considered met for this species.

Studies on *M. punctulatus* suggest that gestation begins in November, with parturition occurring from mid-May to early June (Saïdi *et al.*, 2009; Boscolo Palo *et al.*, 2022). Both juvenile and adult *M. punctulatus* individuals were reported in the Gulf of Trieste in autumn, winter, and spring, suggesting that the species may be using the basin as both a primary and a secondary nursery area. Therefore the second criterion is met for this species, too.

The *T. marmorata* records are in compliance with data from other studies on this species' reproductive biology in the Mediterranean Sea, where late pregnant individuals were found from July to October and post-pregnant individuals from September to February, as well as in May and August (Capapé, 1979; Consalvo *et al.,* 2007; Chatzispyrou *et al.,* 2021).

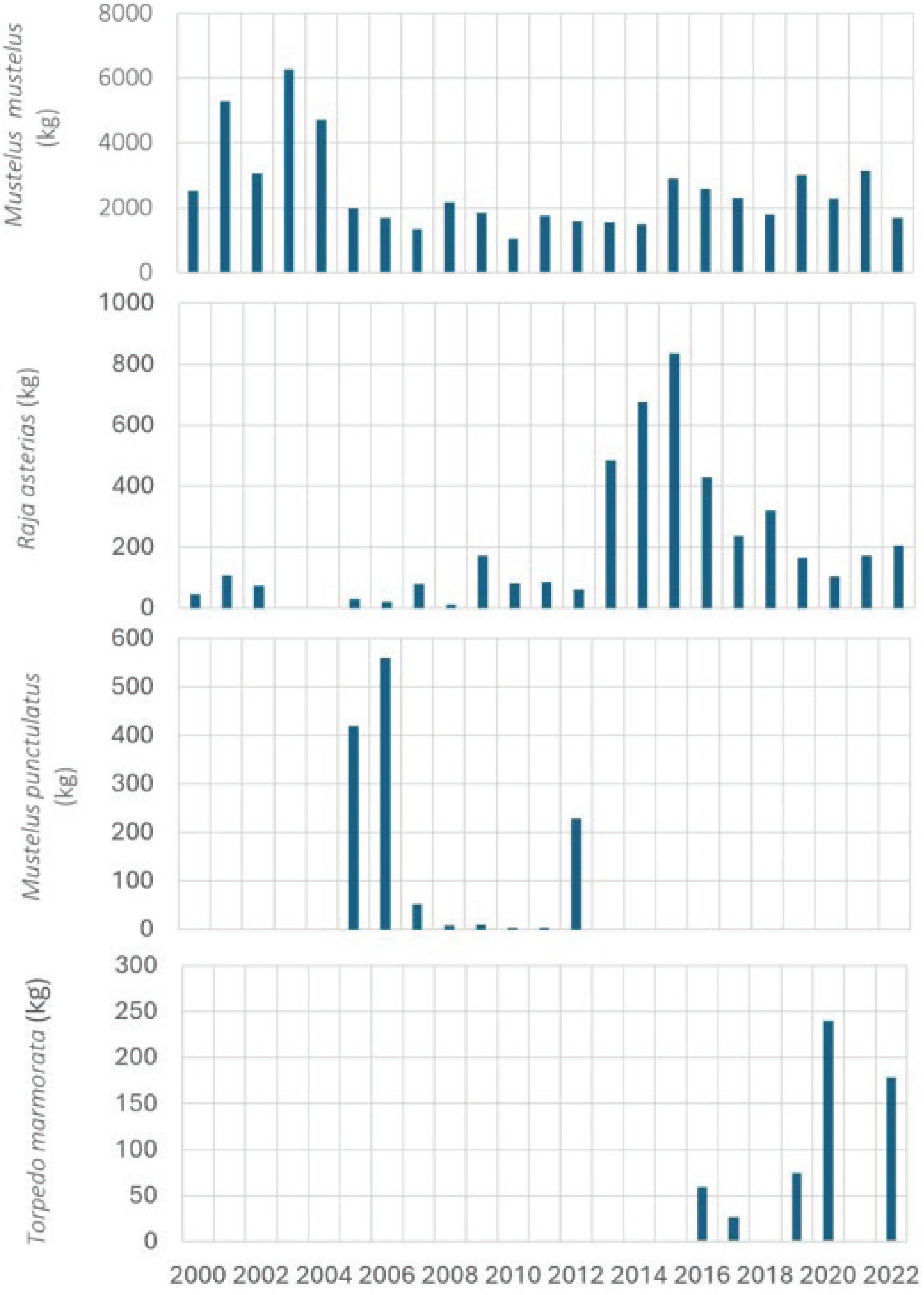

Fig. 4: Annual bycatch (kg) of four of the five species included in this study, based on data from the Slovenian Fisheries Institute (BIOSWEB, 2025).

Fig. 4: Letni prilov (kg) za štiri od petih vrst, vključenih v to raziskavo, na podlagi podatkov Inštituta za ribištvo (BIOSWEB, 2025).

Tab. 6: Suitability of the abiotic conditions in the Gulf of Trieste for the five species included in this study.
Tab. 6: Primernost abiotskih dejavnikov (pogojev) v Tržaškem zalivu za pet vrst, vključenih v to raziskavo.

	Substrate type	Climate	Salinity (psu)	Depth (m)
M. mustelus	sandy, muddy, or detritic bottoms, sometimes swim midwater	temperate	tolerates Mediterranean salinity level (38–40)	5–624 (usually 5–50)
M. punctulatus	inshore, sandy and muddy bottoms	subtropical	tolerates Mediterranean salinity level (38–40)	0–250
T. marmorata	seagrass areas, rocky reefs and adjacent soft bottoms	subtropical (< 20 °C)	tolerates Mediterranean salinity level (38–40)	2–270
R. asterias	benthic in inshore waters on sandy or muddy bottom	subtropical	tolerates Mediterranean salinity level (38–40)	2–700 (usually 20–50)
A. bovinus	demersal and semi-pelagic in estuaries, lagoons and on the continental shelf	subtropical	tolerates Mediterranean salinity level (38–40) as well as lower salinity	0–500
Gulf of Trieste	rocky coastal area, sandstone habitat types overgrown by algal vegetation, seagrass meadows, silty clay, biogenic detritus and soft bottom	temperate–humid subtropical (Cfa)	35–38	max. 37

These results indicate that the occurrence of juvenile, newborn, and adult *T. marmorata* in the Gulf of Trieste is typical of an area where a potential nursery might be located. Therefore, the second criterion is met for this species as well.

Research on the reproductive biology of *R. asterias* in the Mediterranean Sea suggests that juveniles are especially common from January to March and from July to September (Stehmann & Bürkel, 1984; Serena & Relini, 2006). Given that both juveniles and adults were caught in the Gulf of Trieste during and after the typical period when this species reproduces, this may indicate that the area is being used as a nursery. Therefore, the second criterion is also met for this species.

While not much information is available on the reproductive habits of *A. bovinus* in the Mediterranean Sea, the species' mating season generally begins in spring and ends in autumn (Michael, 1993). The reported catches of *A. bovinus* in the Gulf of Trieste align with this general pattern, as they occurred during the assumed reproductive period, with parturition probably occurring elsewhere. Since the juveniles recorded were close to the size at maturity reported for the species, they were likely born the previous year and migrated to the northern Adriatic from another area, possibly Amvrakikos Gulf, during the summer. This means that both adults and juveniles may be transient in the area rather than using it as a nursery.

The third criterion – that juveniles use the area or habitat repeatedly over the years – was also fulfilled by four of the five species. Since no direct tracking data were available, bycatch records from this study, as well as data from the website of the Slovenian Fisheries Institute (ZZRS) reported for different years were used as a substitute. *M. mustelus* was by far the most abundantly caught species included in this study (Fig. 4), with catch records on the ZZRS website exceeding 1000 kg each year (BIOSWEB, 2025). Additionally, the specimens included in the analysis were caught 10 years apart. Therefore, the third criterion is met for this species.

The only catch records available for *M. punctulatus* span the years from 2005 to 2012 (Fig. 4), with no records thereafter (BIOS, 2025). It is possible that *M. punctulatus* and *M. mustelus* records have been conflated, as the two closely related species are known to be frequently misidentified (Marino *et al.*, 2018). One distinguishing feature between the species is size at sexual maturity, estimated at 90 cm for males and 100 cm for females in *M. punctulatus*, compared with 70–80 cm for both sexes in *M. mustelus* (Lipej *et al.*, 2011). Consequently, individuals representing adult *M. mustelus* may have been misidentified as

Tab. 7: Abundance of selected prey items of juveniles of all five species included in this study.
Tab. 7: Številčnost (abundanca) izbranega plena mladih primerkov vseh petih vrst, vključenih v to raziskavo.

Species	**Food preference / specialization of juveniles**	**Abundance**	**Sources**
M. mustelus	**Crustaceans**		Maynou *et al.*, 2004; Farrugio & Soldo, 2015; BIOSWEB, 2025
	Squilla mantis	seasonally abundant (summer)	
	Maja squinado	no data	
M. punctulatus	**Crustaceans**		Maynou *et al.*, 2004; Farrugio & Soldo, 2015; Bacci *et al.*, 2024
	Squilla mantis	seasonally abundant (summer)	
	Ethusa mascarone	present	
T. marmorata	**Teleost fish**		Farrugio & Soldo, 2014; 2015; BIOSWEB, 2025
	Boops boops	seasonally abundant (summer)	
	Spicara spp.	no data	
	Soleidae	seasonally abundant (fall)	
	Crustaceans		
	Cypridina mediterranea	no data	
	Cephalopods		
	Loligo vulgaris	seasonally abundant (winter)	
	Sepia elegans	seasonally abundant (summer)	
R. asterias	**Crustaceans**		Farrugio & Soldo, 2014; 2015; Bacci *et al.*, 2024
	Ethusa mascarone	present	
	Polybius sp.	present	
	Cephalopods		
	Loligo vulgaris	seasonally abundant (winter)	
	Sepia sp.	seasonally abundant (summer)	
	Teleost fish		
	Gobius niger	present	
	Cepola macropthalma	no data	
A. bovinus	**Gastropods**		Bacci *et al.*, 2024
	Gibbula magus	no data	
	Crustaceans		
	Paguristes eremita	present	

juvenile *M. punctulatus*, which could explain why only juveniles of *M. mustelus* have been recorded throughout the study period. The specimens analyzed in this study were caught in 2002, 2003, 2011, and 2014, suggesting that not all catches may be represented in the ZZRS database. As these records span several years, the third criterion is considered met for *M. punctulatus*, too.

There are virtually no catch records of *T. marmorata* on the ZZRS website before 2016, after which irregular annual records are reported, ranging from 30 to 283 kg (Fig. 4). The specimens analyzed in this study were caught between 2011 and 2014, suggesting that not all historical catches are represented in the ZZRS database. Given that juveniles were caught in multiple years, the third criterion is met for this species as well.

R. asterias has been reported every year since 2000, except for 2003 and 2004; however, it should be noted that similar reporting gaps are present for several other species during the mentioned two years, suggesting that the pattern may not accurately reflect landings of *R. asterias* for that period (BIOSWEB, 2025). The *R. asterias* specimens included in this study were caught between 2011 and 2016, with juveniles captured in each year. Therefore, the third criterion is also met for this species.

For *A. bovinus*, no assumptions can be made regarding whether juveniles were recorded across multiple years. Two studies included specimens caught in 2005 (Dulčić *et al.*, 2008; Lipej *et al.,* 2009), while Uhan (2016) reported two adult specimens added to the collection of the Marine Biology Station of the National Institute of Biology in 2014. However, since the ZZRS website does not provide catch records for this species, no conclusion can be drawn regarding the third criterion based on the available data.

Fulton's condition factor and additional criteria

Combining Fulton's condition factor values with the biotic and abiotic conditions of the Gulf of Trieste allowed for an extension of the analysis to ecological factors that could not be assessed through the main nursery area criteria alone.

The mean Fulton's condition factor for *M. mustelus* (Tab. 3) was well within the expected range for the species, as both lower and higher values have been reported in the Mediterranean Sea (Filiz & Mater, 2002; Ismen *et al.*, 2007; Ozcan & Başusta, 2018; Colombelli & Bonanomi, 2022). However, only juvenile specimens had available biometric data, therefore the condition factor values could not be directly compared between juveniles and adults.

As with *M. mustelus*, only juvenile specimens of *M. punctulatus* had available biometry; therefore, condition factor values in juveniles could not be directly compared with those in adults from this study (Tab. 5). However, when compared to similar studies from the region, the mean value (Tab. 3) is slightly higher than those reported for the Mediterranean (Colombelli & Bonanomi, 2022).

For *T. marmorata,* comparable studies in the Mediterranean have reported lower mean values for Fulton's condition factor (Filiz & Mater, 2002; Ismen *et al.,* 2007; Duman & Başusta, 2013); accordingly, the specimens in this study appear to exhibit above-average mean condition factor values (Tab. 3).

Fulton's condition factor mean for *R. asterias* was lower than values reported by comparable studies from the northern Adriatic, which also included a higher proportion of juveniles than adults (Karakulak *et al.*, 2006; Ferrà *et al.,* 2016). It should be noted that some of the specimens in Ferrà *et al.* (2016) originated from the Gulf of Trieste, and the authors recognized the area as an aggregation site for the species (Ferrà *et al.*, 2016).

The mean Fulton's condition factor for *A. bovinus* was within the range reported in comparable studies from the Mediterranean (Başusta *et al.,* 2012; Tsikliras & Dimarchopoulou, 2021; Colombelli & Bonanomi, 2022).

Analyses of the stomach contents of *M. mustelus* suggest that it is an opportunistic predator, feeding on a wide range of prey items, including benthic invertebrates and fishes, as well as prey of varying sizes and morphologies (Ahmed *et al.,* 2022). In the northern Adriatic, decapod crustaceans are considered the most important and frequent prey for juveniles and are present in all seasons (Jardas *et al.*, 2007). This indicates that prey resources for juveniles are likely available throughout the year, supporting the suitability of the Gulf of Trieste as a potential nursery area.

Juveniles of *M. punctulatus* in the northern Adriatic have also been shown to mainly feed on crustaceans – unlike adults, which preferentially consume cephalopods (Lipej *et al.*, 2011) – however, there is no clear indication of competition for food resources with *M. mustelus* juveniles (Tab. 6 and Tab. 7), suggesting that the two species may co-occur within the same nursery area.

Analyses of the diet of *T. marmorata* in the Mediterranean show that both juveniles and adults primarily feed on teleost fishes (Chatzispyrou *et al.,* 2021) and cephalopods (Capapé *et al.*, 2007). The species has also shown local dietary specialization (Chatzispyrou *et al.*, 2021). This ability might be especially useful in communal nursery areas to avoid competition for food with juveniles of other species.

Diet analyses of *R. asterias* in the Adriatic Sea show that both juveniles and adults primarily feed on decapods, with cephalopods and teleost fishes occurring in smaller proportions (Sviben *et al.*, 2019). Sviben *et al.* (2019) further report that specimens from the Slovene sector of the Gulf of Trieste exhibited the highest average prey weight, prey diversity, and meal value, suggesting plentiful food resources for the species. This may be particularly relevant in the context of nursery function, especially in a multi-species setting where juveniles of other taxa also primarily consume decapods.

The diet of juvenile *A. bovinus* in the northern Adriatic consists almost exclusively of gastropods, while adults also consume fish (Lipej *et al.*, 2025). The disk width (DW) at birth of specimens from the northern Adriatic was greater than that observed in specimens from other parts of the Mediterranean. Correspondingly, adult individuals from this region attained some of the highest body weights recorded across the species distribution range (Dulčić *et al.*, 2008; Lipej *et al.,* 2009). Dulčić *et al.* (2008) and Lipej *et al.* (2009) suggested that these differences may be related to the apparent absence of parasitic infections in the examined specimens. If so, low parasite prevalence may be another habitat characteristic that favors the presence of this species (Tab. 6 and Tab. 7).

Based on these results, the Gulf of Trieste is most likely used as a communal juvenile habitat (secondary nursery area) by four of the five species examined, as it fulfills the three criteria for a nursery area for all species except *A. bovinus*. It also satisfies the first criterion of a juvenile nursery area as defined by Martins *et al.* (2018) (Tab. 2). However, due to the limited number of specimens and lack of tracking data, it is difficult to assess the contribution of the area to juvenile recruitment. The abiotic (Tab. 6) and biotic (Tab. 7) conditions in the Gulf of Trieste are consistent with those expected of a nursery area for all five species: the gulf is relatively shallow, features both soft-sediment and hard-substrate habitats, and contains abundant prey resources for each species. Some species have been shown to exhibit dietary flexibility in habitats where they overlap with other species in order to avoid intra- and inter-specific competition, which can also depend on their mode of reproduction (Capapé et al., 2003; Chatzispyrou *et al.*, 2021; Ahmed *et al.*, 2022; Finotto *et al.,* 2023). Additionally, primary production measurements suggest that the trophic conditions in the area have not significantly changed in over a decade (Cibic *et al.*, 2022) and have therefore been stable enough to potentially aid the development of a nursery area. None of the five species have any natural predators in the area, and they all occupy high trophic levels typical of predators at the top of the food chain (Lipej *et al.,* 2011; Sviben *et al.,* 2019; Ahmed *et al.,* 2022; Lipej *et al.*, 2025).

The characteristics of the Gulf of Trieste indicate that the habitat could support a communal nursery area for all five species. None of the species in this study are subject to protection in the region; in Slovenia, specifically, there are no ongoing regular monitoring programs regarding sharks and rays (Lipej *et al.*, 2024). Despite the presence of several suitable sites that could serve as potential nursery areas and already have some form of protection – both in Slovenia (the natural monuments Cape Madonna and Debeli rtič, the Strunjan Nature Reserve, the Sečovlje Salina Nature Park, and Landscape Park Strunjan) and in Italy (the Miramare Marine Protected Area, Duino Cliffs Nature Reserve, and Cavana di Monfalcone) – none have yet been designated or evaluated as potential nursery areas (Lipej *et al.*, 2024; WDPA, 2025). Additionally, juveniles of other elasmobranch species, such as *Carcharhinus plumbeus, Alopias vulpinus, Squalus acanthias, Raja clavata, Dasyatis pastinaca, Pteroplatytrigon violacea*, and *Myliobatis aquila*, have also been documented in the Gulf of Trieste over the 24-year period (Fig. 4). However, they were not included in this study as there were insufficient specimens of each species available for further analysis (Lipej *et al.*, 2008; 2016; 2022a; 2022b; 2023). Regardless, this highlights the potential importance of the area as a nursery for an even higher number of species than those considered in this study. Given the limited available data on elasmobranchs in the region, increased efforts to gather more information and conduct accurate future analyses are needed. A proper assessment of the real status of elasmobranch species in the area is essential for informing effective conservation and management measures.

ALI JE TRŽAŠKI ZALIV POTENCIALNO OBMOČJE ODRAŠČANJA (JASLICE) ZA DOLOČENE VRSTE HRUSTANČNIC?

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POVZETEK

*Avtorji poročajo o izsledkih raziskave, katere namen je bil ugotoviti, ali Tržaški zaliv izpolnjuje merila za območje odraščanja, kot jih definirajo različni viri, predvsem Heupel s sodelavci (2007). Analiza je temeljila na osebkih hrustančnic iz zbirke Morske biološke postaje Piran (Nacionalni inštitut za biologijo, Slovenija) in je vključevala primerke petih vrst (*Mustelus mustelus, M. punctulatus, Torpedo marmorata, Raja asterias *in* Aetomylaeus bovinus*), ujetih kot prilov v obdobju 24 let. Štiri od petih vrst (razen vrste* A. bovinus*) so izpolnile vsa tri merila. Glede na analizirane podatke bi Tržaški zaliv lahko obravnavali kot skupno območje odraščanja mladic za preučevane vrste. Poleg tega zapisi o mladih primerkih drugih vrst hrustančnic, o katerih so poročali v obdobju raziskave na tem območju, kažejo na potencialen pomen tega okolja kot območja odraščanja tudi za druge vrste.*

Ključne besede: hrustančnice, skotitev, merila za območje odraščanja, abiotski pogoji, prilov, severni Jadran

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NEW DATA ON THE OCCURRENCE AND MORPHOLOGY OF THE ARMLESS SNAKE EEL, *DALOPHIS IMBERBIS* (OPHICHTHIDAE), FROM THE NORTHEASTERN MEDITERRANEAN SEA

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ABSTRACT

The armless snake eel, Dalophis imberbis*, is an ophichthid eel widely distributed in the Mediterranean Sea, but comparatively rare in the eastern basin. This study examined three specimens from Iskenderun Bay (northeastern Mediterranean Sea, Türkiye), which were identified based on standard morphological diagnostic characters and measured for key morphometric traits. The individuals were captured at shallow coastal depths, contributing new distributional and ecological data for the species in the eastern Levant Basin. Morphometric results are consistent with previously published Mediterranean data, although minor variations were observed among selected proportional measurements. These findings provide additional evidence for the presence of* D. imberbis *in Turkish waters and support the view that the species forms part of the established ichthyofauna of the eastern Mediterranean.*

Key words: Anguilliformes, Ophichthidae, Levant Basin, occurrence

NUOVI DATI SULLA PRESENZA E LA MORFOLOGIA DELLA BISCIA DI MARE, *DALOPHIS IMBERBIS* (OPHICHTHIDAE), NEL MEDITERRANEO NORD-ORIENTALE

SINTESI

La biscia di mare, Dalophis imberbis*, è un'anguilla della famiglia Ophichthidae ampiamente distribuita nel Mediterraneo, ma relativamente rara nel bacino orientale. In questo studio gli autori hanno esaminato tre esemplari provenienti dalla baia di Iskenderun (Mediterraneo nord-orientale, Türkiye), identificati sulla base dei caratteri diagnostici morfologici standard e misurati per i principali parametri morfometrici. Gli individui sono stati catturati in acque costiere poco profonde, fornendo nuovi dati distributivi ed ecologici per la specie nel bacino levantino orientale. I risultati morfometrici sono coerenti con i dati mediterranei precedentemente pubblicati. L'articolo fornisce ulteriori prove della presenza di* D. imberbis *nelle acque turche e supporta l'ipotesi che la specie faccia parte dell'ittiofauna stabilmente insediata del Mediterraneo orientale.*

Parole chiave: Anguilliformes, Ophichthidae, Bacino del Levante, presenza

INTRODUCTION

The family Ophichthidae includes 62 genera and 374 species, among which is the armless snake eel, *Dalophis imberbis* (Delaroche, 1809) (Fricke *et al*., 2026). The distribution range of *D. imberbis* extends from Mauritania to Spain and throughout the Mediterranean Sea (Froese & Pauly, 2026), where the species occurs at depths ranging from 5.4 m (Sabrina Lo Brutto, pers. comm.) to 115 m (Busalacchi *et al*., 2010). *D. imberbis* is considered an established member of the Mediterranean anguilliform fauna (Kovačić *et al.,* 2021) and has been found in the Turkish Aegean and Mediterranean waters (Bilecenoğlu, 2024). However, most occurrence records originate from the western and central Mediterranean basins (*e.g*., Italian waters, Bonifazi *et al.,* 2019; Libyan waters, Elbaraasi *et al.,* 2019; Adriatic Sea, Soldo & Bakiu, 2021; Algerian waters, Alkhalili *et al.,* 2025). In contrast, its presence in the eastern Mediterranean has been documented only through sporadic records (*e.g*., Israeli waters, Golani, 2005; Syrian waters, Capapé *et al.,* 2021). Despite the species' broad distribution in the Mediterranean Sea, information on its occurrence and biological characteristics in the eastern Mediterranean remains limited. Therefore, the present study provides new data on the distribution and morphometric characteristics of *D. imberbis* in the northeastern Mediterranean Sea based on three specimens collected from Iskenderun Bay.

MATERIAL AND METHODS

Three specimens of *Dalophis imberbis* were captured in Iskenderun Bay (Fig. 1) by a commercial otter trawler (M/V Faik Baba; 400 hp) fitted with a net with a cod-end mesh size of 44 mm (stretched mesh, knot-to-knot) and a net opening width of 20 m. Trawling operations were conducted over a mixed mud–sand bottom at depths ranging from 54 to 69 m, at towing speeds of 2.2 to 2.8 knots. The specimens were captured at the following locations and depths: specimen no. 1 was caught at a depth of 63 m (36°47′4.5″–36°41′15.7″ N; 36°6′43.2″–36°5′19.7″ E); specimen no. 2 at 61 m (36°41′43.8″–36°44′47.0″ N; 36°4′52.3″–36°3′30.7″ E); and specimen no. 3 at 55 m (36°34′1.5″–36°34′57.8″ N; 36°1′9.7″–36°3′14.4″ E). Sampling was performed on 25 and 26 February 2013.

After capture, the specimens were kept frozen at −18 °C on board until fixation and were subsequently preserved in a 5% borax-buffered formalin solution. Species identification followed Bauchot (1986) and the scientific nomenclature conforms to the Fricke *et al*. (2026). Previous records of *D. imberbis* covering the period 1845-2026 were obtained from the Global Biodiversity Information Facility (GBIF, 2026), available at the following web page: https://www.gbif.org/species/2405106. The coordinates of these records were plotted using cartographic software QGIS version 3.40 to generate a distribution map of the species throughout the Mediterranean Sea (Fig. 1). The present description is based on the examination of the three specimens from Iskenderun Bay, which are deposited in the museum of the Department of Hydrobiology, Istanbul University, under catalogue numbers 2013-1052, 2013-1053, and 2013-1054.

RESULTS AND DISCUSSION

Description of the examined specimens (nos. 1–3, Fig. 2): body extremely cylindrical and elongated, snout pointed, lower jaw symphysis closer to the anterior border of the eye than to the tip of the snout, eyes minute and covered by skin; anterior nostrils short and tube-shaped, posterior nostrils located above upper lip; teeth conical and slightly curved, uniserial in both jaws, five premaxillary teeth forming a V-shape, small teeth present on vomer; gill openings ranging from midlateral to entirely ventral, crescent-shaped; all fins absent; caudal tip hardened; lateral line with 62–63 preanal pores and 7–8 prebranchial pores; body depth 2.2–2.5% of total length, head length 7.5–8.0% of total length; snout length 18.2–21.2%, eye diameter 5.9–8.1%, and interorbital width 8.0–10.2% of head length; colouration: dorsal surface brownish, tip of upper jaw dark brown, ventral surface whitish. The characteristics of the examined specimens match those reported in the literature, confirming the identification of the collected individuals as *Dalophis imberbis* (Delaroche, 1809). Their length measurements are presented in Tab. 1.

In light of the available literature, *D. imberbis* is considered a native member of the Mediterranean ichthyofauna, exhibiting a broad but highly patchy distribution across the basin. The apparent scarcity of records in several areas is most likely attributable to the species' cryptic behaviour, burrowing lifestyle, and the limited efficiency of conventional sampling methods targeting benthic eel-like species, rather than reflecting true absence. *D. imberbis* is rarely reported off the French coast (Bauchot & Pras, 1980; Béarez *et al*., 2017), while it appears relatively more frequently in Italian waters (Bonifazi *et al*., 2019). In the Adriatic Sea, it occurs at low densities (Likić *et al*., 2015). Further south, spawning activity for the species has been reported from the Bay of Algiers (Bauchot, 1986), whereas its presence along the Maghreb coast remains poorly documented, including in Algeria (Refes *et al*., 2010) and Tunisia (Bradaï *et al*., 2004). This likely reflects undersampling rather than true ab-

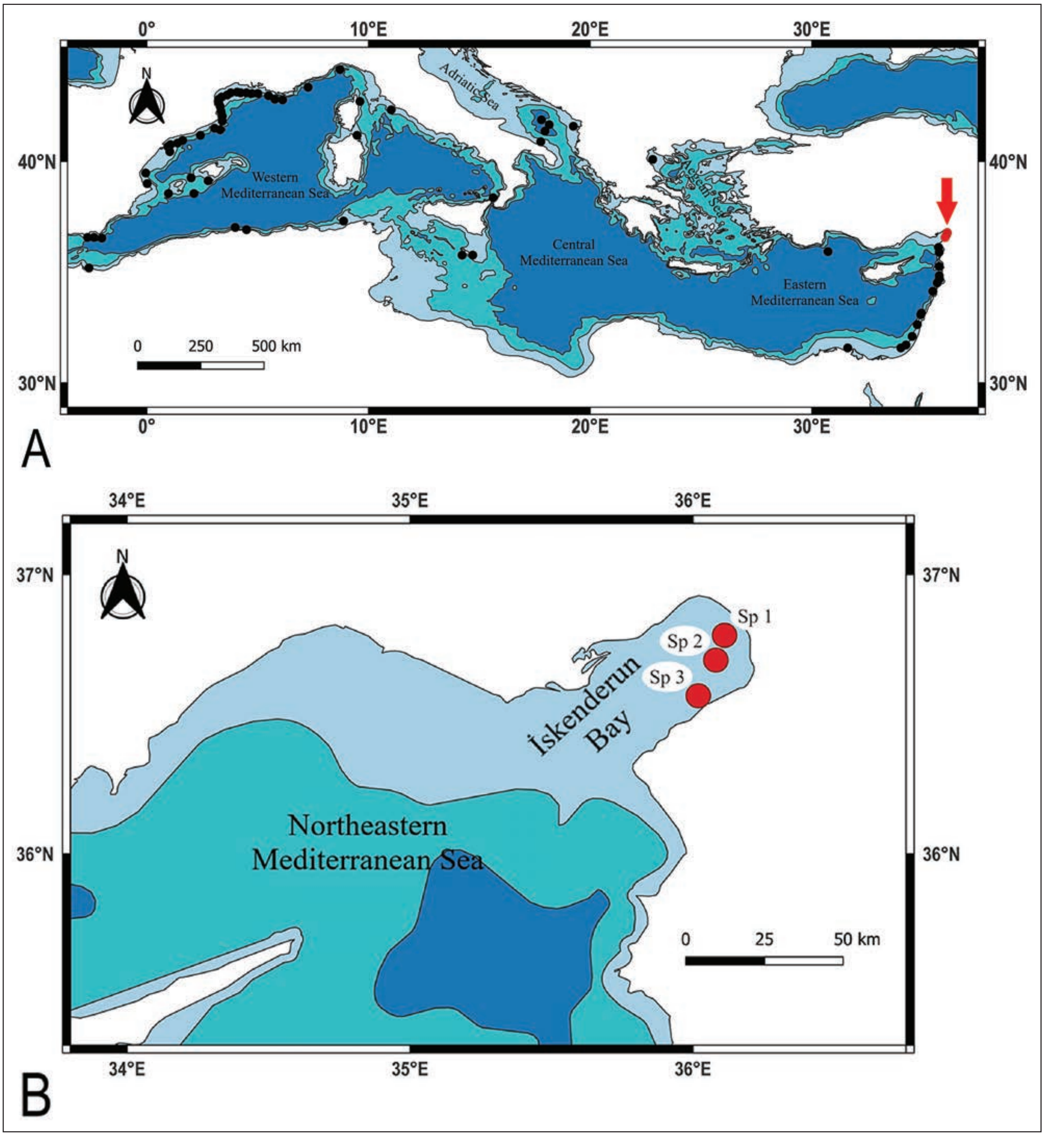

Fig. 1: Previous records (solid black circles) and present specimens (solid red circles, indicated by a solid red arrow) of* Dalophis imberbis *throughout the Mediterranean Sea (a), and a detailed map of the capture localities of the present specimens in Iskenderun Bay (b). The blue bathymetric colour gradient represents depth variation from 0 to 1000 m, from light to dark blue. The isobaths indicate depth contours at 200 m and 1000 m, progressing from the outer to the inner limits of the mapped area.

Sl. 1: Prejšnji zapisi o pojavljanju vrste* Dalophis imberbis *po celotnem Sredozemskem morju (polni črni krogi) in pričujoči osebki (polni rdeči krogi, označeni s polno rdečo puščico) (a) ter podroben zemljevid lokacij ulova pričujočih osebkov v zalivu Iskenderun (b). Modri batimetrični barvni gradient predstavlja spreminjanje globine od 0 do 1000 m, od svetlo do temno modre. Izobate označujejo globinske konture pri 200 m in 1000 m, ki potekajo od zunanjih proti notranjim mejam usmerjenega območja.

Fig. 2: Lateral view of* Dalophis imberbis*; scale (tape measure units) = 10 mm (a). Lateral view of the head of the same specimen; scale (tape measure units) = 10 mm (b). Dentition of the lower jaw; scale bar = 1 mm (c). Photo: Cem Dalyan.

Sl. 2: Stranski pogled na primerek* Dalophis imberbis*; merilo (enote na merilnem traku) = 10 mm (a). Stranski pogled na glavo istega primerka; merilo (enote na merilnem traku) = 10 mm (b). Zobovje spodnje čeljusti; merilo = 1 mm (c). Foto: Cem Dalyan.

sence. Eastwards, records from Greek (Papaconstantinou, 2014) and Turkish waters (Bilecenoğlu, 2024) confirm a continuous occurrence of the species, with the Levant Basin representing the easternmost extent of its distribution (Golani, 2005; El Sayed *et al.*, 2017; Bariche & Fricke, 2020). Therefore, *D. imberbis* should be regarded as a native but under-detected species in the eastern Mediterranean, with long-term monitoring occasionally revealing previously unrecorded occurrences in the region (Saad, 2005; Ali, 2018; Capapé *et al.*, 2021).

However, records derived from citizen science observations, particularly those including georeferenced photographs accessible through the GBIF platform (GBIF, 2026), have significantly improved the resolution of the known distribution of *D. imberbis* in recent years. Still, these opportunistic data cannot replace systematic scientific surveys, which remain essential to address persistent gaps in knowledge regarding the species' life history and population ecology. In this context, the most detailed morphometric study of *D. imberbis* to date has been conducted by Bonifazi *et al.* (2019), who reported selected measurements of 20 specimens out of approximately 200 stranded individuals in the central Tyrrhenian Sea. More recently, Capapé *et al.* (2021) presented morphometric data based on a single specimen from Syrian waters. Although the specimens presented in this study were collected several years prior to their detailed examination, their morphometric data remain valuable for the understanding of *D. imberbis* populations in the eastern Mediterranean. In fact, by reporting measurements of three further specimens captured in the eastern Mediterranean Sea, this study contributes additional morphometric information and enhances knowledge of the species' morphology and distribution in the region.

Although based on a limited number of specimens, the morphometric results of this study provide comparative data for *D. imberbis* from the eastern Mediterranean. Overall, proportional measurements show a high degree of consistency with previous studies, particularly for head length (7.50% TL in the present study vs. 7.03% in Bonifazi *et al.* (2019) and 7.73% in Capapé *et al.* (2021)) and eye diameter (0.52% TL vs. 0.41% and 0.50%, respectively). Similarly, body depth values (2.34% TL) closely match those reported by Bonifazi *et al.* (2019) (2.26% TL), suggesting limited morphological

Tab. 1: Morphometric data of the examined* Dalophis imberbis *specimens (nos. 1–3), presented as individual measurements and percentages of total length (TL). Data from relevant literature are also included for comparison. SE: standard error of the mean; N/A: not available.

Tab. 1: Morfometrični podatki preučenih primerkov vrste* Dalophis imberbis *(št. 1–3), predstavljeni kot posamezne meritve in odstotki celotne dolžine (TL). Za primerjavo so vključeni tudi podatki iz ustrezne literature. SE: standardna napaka aritmetične sredine; N/A: ni na voljo.

Measurements (mm)	**Sp. no 1**	**Sp. no 2**	**Sp. no 3**	**Mean**	**±SE**	**% of mean TL**	**Bonifazi et al. (2019) % of mean TL**	**Capapé et al. (2021) % of mean TL**
TL	234	261	208	234.3	12.5	100	100	100
Preanal length	100.7	117	88	101.9	6.9	**43.5**	N/A	**37.5**
Predorsal length	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9.7
Prepectoral length	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.4
Body depth	5.9	5.6	4.9	5.5	0.3	**2.3**	**2.3**	**1.9**
Head length	18.6	18.6	15.5	17.6	0.8	**7.5**	**7.0**	**7.7**
Eye diameter	1.5	1.1	1.1	1.2	0.1	**0.5**	**0.4**	**0.5**
Preorbital length	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.4
Snout length	3.4	3.9	3.3	3.5	0.2	**1.5**	**1.3**	N/A
Upper jaw length	6.3	6.6	4.4	5.8	0.6	**2.5**	**2.3**	N/A
Lower jaw length	5.3	5.8	3.6	4.9	0.6	**2.1**	N/A	**4.9**
Interorbital distance	1.8	1.5	1.6	1.6	0.1	**0.7**	N/A	**0.6**

variability across Mediterranean populations. Some differences, however, were observed in specific measurements, particularly preanal length, which was slightly higher in the present material (43.49% TL) compared to Capapé *et al*. (2021) (37.50% TL). Such variation may be a reflection of intraspecific variability, limited sample size, or methodological differences among studies, including measurement protocols and specimen preservation conditions. In particular, long-term preservation history, including prolonged freezing, may induce minor tissue shrinkage or deformation, potentially affecting linear morphometric ratios. The absence of several morphometric parameters in previous studies (*e.g.*, predorsal, prepectoral, and preorbital lengths in Bonifazi *et al*. (2019)) further limits direct comparisons but also highlights the added value of the present dataset in complementing the morphological knowledge of the species.

From a broader perspective, the limited availability of morphometric data for *D. imberbis* likely reflects its low economic importance and, consequently, the lack of research priority given to a species not targeted by commercial fisheries. Such situations often result in reliance on opportunistic sampling and incidental captures, with specimens frequently deposited in collections and examined only years later, when taxonomic or faunistic interest arises. In this context, a 13-year interval between collection and detailed analysis, as in the present case, is not unusual for non-commercial, rarely studied benthic species. Museum and institutional collections are thus particularly important, as they provide essential material for retrospective morphological and faunistic studies of poorly known taxa. Such archived specimens allow the reconstruction of distributional and morphological baselines that would otherwise remain undocumented, especially for cryptic and low-priority species such as *D. imberbis*.

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NOVI PODATKI O POJAVLJANJU IN MORFOLOGIJI KAČASTE JEGULJE, *DALOPHIS IMBERBIS* (OPHICHTHIDAE), IZ SEVEROVZHODNEGA SREDOZEMSKEGA MORJA

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POVZETEK

Kačasta jegulja, Dalophis imberbis*, je vrsta iz družine kačastih jegulj (Ophichthidae), ki je široko razširjena v Sredozemskem morju, vendar razmeroma redka v njegovem vzhodnem bazenu. Avtorji so preučili tri osebke iz zaliva Iskenderun (severovzhodno Sredozemsko morje, Turčija), ki so jih določili na podlagi standardnih morfoloških diagnostičnih znakov, izmerjene pa so bile tudi njihove ključne morfometrične lastnosti. Primerke so ujeli v obalnih plitvinah, kar prinaša nove podatke o razširjenosti in ekologiji te vrste v vzhodnem Levantskem bazenu. Rezultati morfometričnih meritev so skladni s predhodno objavljenimi podatki za Sredozemlje, čeprav so bila med izbranimi proporcionalnimi meritvami opažena manjša odstopanja. Te ugotovitve zagotavljajo dodatne dokaze o prisotnosti vrste* D. imberbis *v turških vodah in podpirajo stališče, da ta vrsta predstavlja del ustaljene ihtiofavne vzhodnega Sredozemlja.*

Ključne besede: Anguilliformes, Ophichthidae, Levantski bazen, pojavljanje

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FIRST RECORD OF THE MEDITERRANEAN DEALFISH, *TRACHIPTERUS TRACHYPTERUS* (GMELIN, 1789) (TRACHIPTERIDAE), IN SYRIAN MARINE WATERS

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ABSTRACT

Over the past few decades, the Mediterranean Sea has accommodated an increasing number of fish species arriving from the Atlantic Ocean via the Strait of Gibraltar, as well as from the Indo-Pacific region and the Red Sea via the Suez Canal. The ribbonfish (Trachipteridae) are rare deep-sea fishes only recorded in limited areas of the Mediterranean. The Mediterranean dealfish, Trachipterus trachypterus*, a member of the family Trachipteridae, is scientifically documented here for the first time from the Syrian coast (eastern Mediterranean).*

Key words: Mediterranean, Trachipteridae, Syrian marine water, *Trachipterus trachypterus*

PRIMA SEGNALAZIONE DEL PESCE NASTRO, *TRACHIPTERUS TRACHYPTERUS* (GMELIN, 1789) (TRACHIPTERIDAE), NELLE ACQUE MARINE SIRIANE

SINTESI

Negli ultimi decenni, il Mediterraneo ha accolto un numero crescente di specie ittiche provenienti dall'Oceano Atlantico attraverso lo Stretto di Gibilterra, nonché dalla regione Indo-Pacifica e dal Mar Rosso attraverso il Canale di Suez. I pesci nastro (Trachipteridae) sono rari pesci di acque profonde, segnalati solo in aree limitate del Mediterraneo. Nell'articolo il pesce nastro, Trachipterus trachypterus*, appartenente alla famiglia Trachipteridae, viene documentato scientificamente per la prima volta lungo la costa siriana (Mediterraneo orientale).*

Parole chiave: Mediterraneo, Trachipteridae, acque marine siriane, *Trachipterus trachypterus*

INTRODUCTION

Over the past few decades, the Mediterranean Sea has accommodated an increasing number of fish species arriving from the Atlantic Ocean via the Strait of Gibraltar (Azzurro *et al.*, 2022), as well as from the Indo-Pacific region and the Red Sea via the Suez Canal (Galil *et al.*, 2015; Ibrahim *et al.*, 2022). This biogeographic expansion signals changing ecological dynamics within the marine ecosystem of the area. Such expansion is promoted by climate change, hydrological processes, and human activities, and reflects the species' need to spread into new habitats that ensure their survival (Armas & Vila, 2019). Thus, the Mediterranean Sea occasionally witnesses the emergence of species far from their original environments, driven to seek prey in new areas (Ibrahim *et al.*, 2019; Orfanidis *et al.*, 2019).

The ribbonfish (Trachipteridae) are rare deep-sea fishes globally distributed in the eastern Atlantic, including the western Mediterranean, from Morocco to South Africa (Heemstra & Kannemeyer, 1986), as well as in the western Pacific (Japan and New Zealand) and the southeastern Pacific (Nakamura *et al.*, 1986). *Trachipterus trachypterus* (Gmelin, 1789), one of the family's member species, is characterized by elongated, ribbon-like bodies and large, elongated dorsal fins (Carpenter, 2002). It is usually found in bathypelagic habitats at depths between 300 and 600 m (Froese & Pauly, 2025). The species has previously been reported as rare in some areas of the Mediterranean Sea (*e.g.*, Garibaldi, 2015; Albano *et al.*, 2022; Geraci *et al.*, 2022; Gökoğlu & Özen, 2021). In the present study, *Trachipterus trachypterus* is scientifically documented for the first time from the Syrian coast (eastern Mediterranean).

MATERIAL AND METHODS

On 19 October 2025, a local fisherman caught a single *T. trachypterus* specimen using longline fishing in the marine waters off the city of Baniyas, Syria (N35°14′35.11″, E35°55′12″; Fig. 1). The presence of the species in the area came under attention ichthyologists through cooperation with fishermen. This specimen was identified following the criteria in Figueiredo *et al.* (2008); Albano *et al.* (2022), and Geraci *et al.* (2022). Meristic counts were taken, and morphometric measurements were recorded to the nearest 0.5 cm or 0.1 g. An X-ray of the specimen was performed to determine the number of vertebrae and ensure an accurate identification of the species. The specimen was then photographed, preserved in 7% formaldehyde, and deposited as a reference sample (ref. no. HIMR-2026-TA) at the fisheries laboratory of the High Institute of Marine Research, Latakia University (Latakia, Syria).

RESULTS AND DISCUSSION

A specimen of the Mediterranean dealfish, *Trachipterus trachypterus* (Gmelin, 1789) (Fig. 2), was caught at a depth of 850 m. The specimen was scaleless, with a lateral line of 80 forward-directed spines tapering from back to front. Its morphological characters were as follows: body long, significantly compressed and wide, with the maximum width midway between the head and the anus, and tapering towards the caudal fin; eyes large; mouth large and mobile, projecting forward and downwards; dorsal fin long, extending along the entire body, pectoral and pelvic fins relatively small. Coloration: body shiny silver with a light black spot behind the head and a black marking extending from mouth towards head up to the beginning of dorsal fin; dorsal fin transparent orange-red. The specimen's measurements and counts are presented in Table 1.

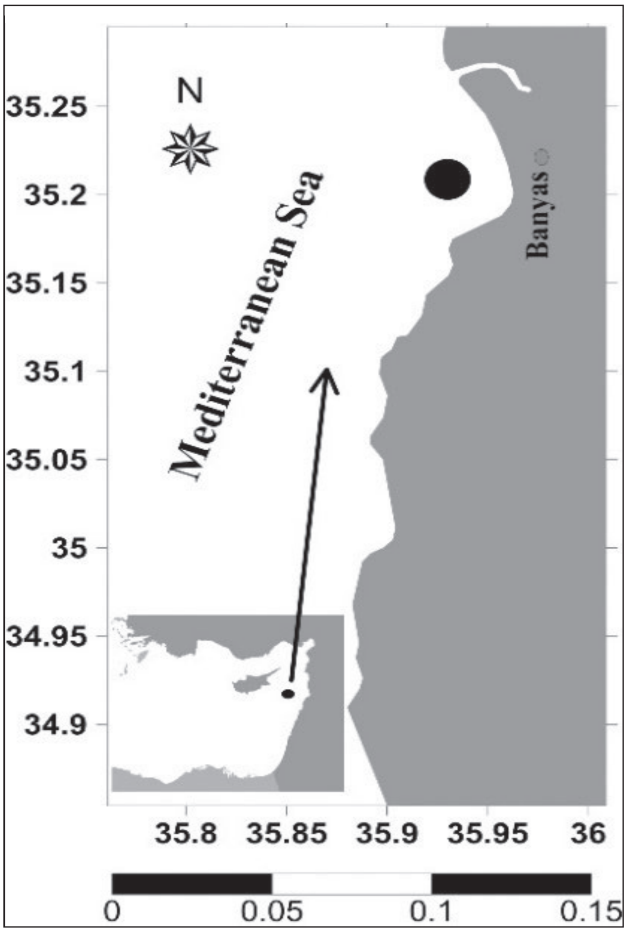

Fig. 1: Map showing the fishing area where the* T. trachypterus *specimen was caught, off the city of Baniyas, Syria.

***Sl. 1: Zemljevid obravnavanega območja z lokaliteto Baniyas, kjer je bil ujet primerek vrste* T. trachypterus.**

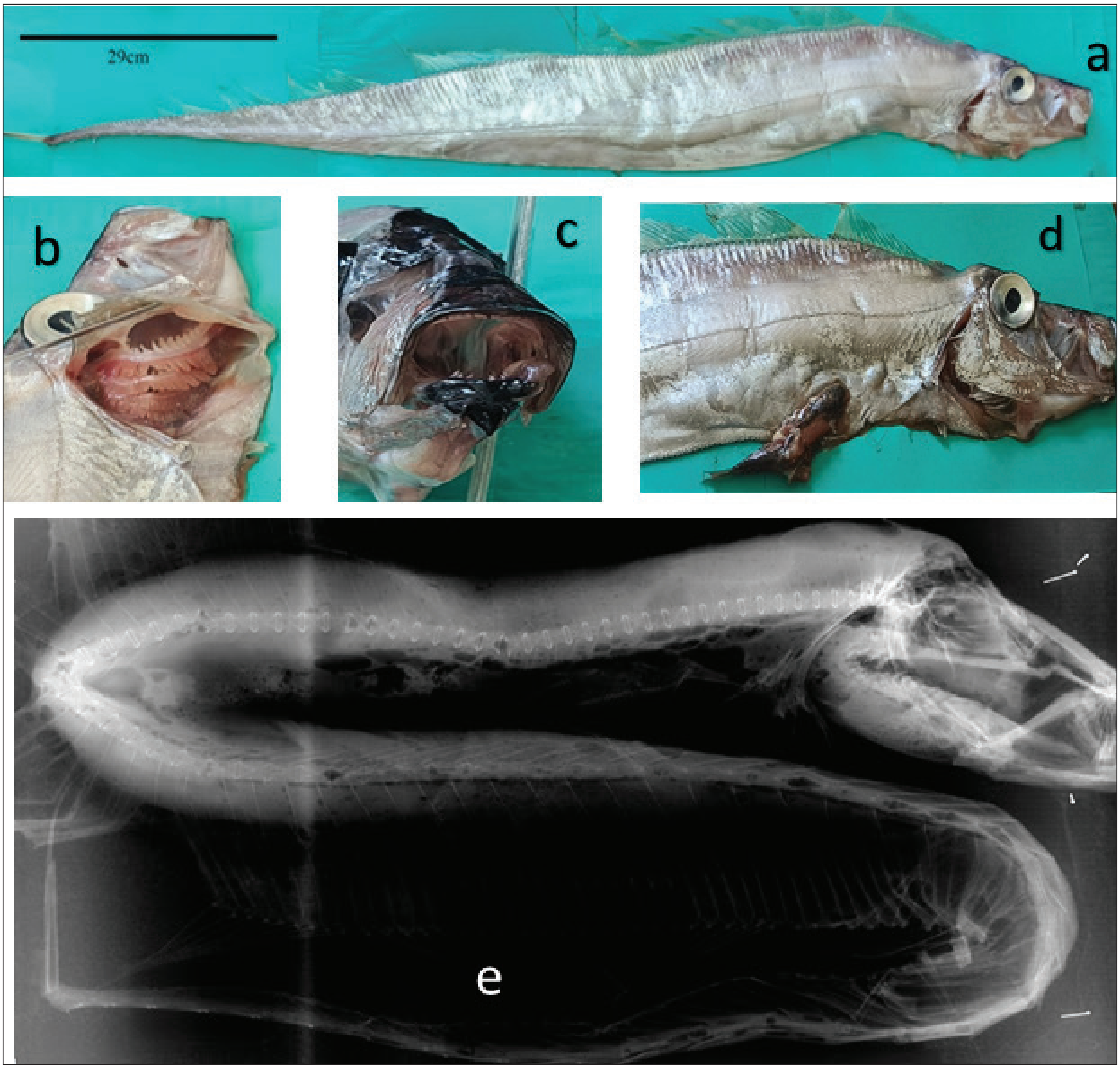

Fig. 2: Specimen of* T. trachypterus *collected from Syrian marine waters: (a) full lateral view; (b) fresh gill rakers; (c) head showing black marking; (d) post-dissection view, with stomach containing remains of a semi-digested local fish; (e) x-ray image of the vertebral column.
Sl. 2: Primerek vrste* T. trachypterus*, ujet v sirskih morskih vodah: (a) stranski pogled na celoten primerek; (b) sveži škržni izrastki; (c) glava s črno pego; (d) pogled po sekciji z želodcem z ostanki delno prebavljenih lokalnih rib; (e) x-ray posnetek hrbtenice.

Its morphological features are consistent with those reported for *T. trachypterus* by Figueiredo *et al.* (2008), Lipej *et al.* (2018), Albano *et al.* (2022), and Geraci *et al.* (2022).

T. trachypterus is considered a rare mesopelagic species, typically found stranded in deep waters across various regions of the Mediterranean Sea, including the Adriatic, Ionian, and Aegean Seas, Spain, the Strait of Sicily, and Türkiye (Lipej *et al.*, 2018; Macali *et al.*, 2020; Albano *et al.*, 2022, Geraci *et al.*, 2022; Stipa *et al.*, 2022). As previous surveys (Ibrahim *et al.*, 2025) did not document *T. trachypterus* in Syrian waters, this study reports the first record of the species on the Syrian coast. This new record, along with that reported from the Gulf of Antalya, Türkiye (Gökoğlu & Özen,

Tab. 1: Morphometric data of the *T. trachypterus* ***specimen caught off the coast of Baniyas, Syria.***
Tab. 1: Morfometrični podatki za primerek vrste *T. trachypterus****, ujet ob obali Baniyas, Sirija.***

Characteristics	**Measurement (cm or g) / Counts**	**% of total length**
Total length	138	-
Body depth (behind the head)	13.5	9.78
Body depth (near the tail)	4.5	3.26
Head Length	15	10.86
Eye dimeter	4	2.89
Pupil diameter	1.5	1.08
Mouth diameter	5.5	3.98
Caudal fin length	12	8.88
Total weight	973.52	-
No. teeth in lower jaw	7	-
No. teeth in upper jaw	7	-
No. dorsal fin rays	167	-
No. spines on lateral line	80	-
No. vertebra in vertebral column	89	-

2021), reveals that *T. trachypterus* has spread its distribution pattern to the eastern Mediterranean, and highlights the need for developing an effective and comprehensive management plan to monitor the species in this region.

From a marine biodiversity perspective, this first record of *T. trachypterus* in Syrian marine waters reflects significant ecological changes that warrant monitoring due to potential impacts on local native species. The arrival of Atlantic species in the Mediterranean Sea may be a result of global warming and/or changes in ocean current patterns, facilitating the dispersion of marine biota into the region (Albano *et al.*, 2024). In addition, the establishment of this species may be supported by the available ecological niches and abundant food resources in Syrian marine waters (Gilaad *et al.*, 2017). The increasing frequency of new fish records off the Syrian coast, as reported by Ibrahim *et al.* (2025), underscores the need for structured survey programmes to detect non-native and exotic species, complemented by effective species identification methods such as eDNA metabarcoding (Ibrahim *et al.*, 2023; Xanthopoulou *et al.*, 2025).

CONCLUSIONS

This article confirms, for the first time, the presence of the Atlantic fish species *Trachipterus trachypterus* in the marine waters of Syria (eastern Mediterranean). The arrival of this species into the area may be attributed to global warming and/or changes in ocean current patterns.

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PRVI ZAPIS O POJAVLJANJU KOSICE, *TRACHIPTERUS TRACHYPTERUS* (GMELIN, 1789) (TRACHIPTERIDAE), V SIRSKIH MORSKIH VODAH

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POVZETEK

V zadnjih nekaj desetletjih se v Sredozemskem morju pojavlja vse večje število vrst rib, ki prihajajo iz Atlantskega oceana prek Gibraltarske ožine, pa tudi iz indo-pacifiške regije in Rdečega morja prek Sueškega prekopa. Kosice (Trachipteridae) so redke globokomorske ribe, ki se pojavljajo le na omejenih območjih Sredozemskega morja. Avtorji sporočajo o prvem znanstveno dokumentiranem pojavljanju kosice, Trachipterus trachypterus*, iz družine Trachipteridae, s sirske obale (vzhodno Sredozemlje).*

Ključne besede: Sredozemsko morje, Trachipteridae, sirske morske vode, *Trachipterus trachypterus*

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ON THE OCCURRENCE OF THE CURRENTLY LARGEST RECORDED *PAGELLUS ERYTHRINUS* (SPARIDAE) IN THE TYRRHENIAN SEA (ITALY)

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ABSTRACT

This paper presents an update of the maximum size of Pagellus erythrinus*, based on a comprehensive list of georeferenced occurrences up to January 2026. An exceptionally large specimen of* P. erythrinus *was captured using a commercial gillnet at a depth of 65 m on a muddy-rocky seabed off Civitavecchia (Rome). This specimen measured 660 mm in total length and had a wet weight of 4,082 g. The species has been recorded across a wide depth range (1–300 m) in over twenty intermittent localities in the Atlantic Ocean and the Mediterranean Sea between 1983 and 2026. This study confirms the largest specimen of* P. erythrinus *recorded to date. This ichthyological note contributes a key parameter for life-history studies and fisheries science.*

Key words: common pandora, maximum length, maximum weight, central Mediterranean Sea

SEGNALAZIONE DELL'ESEMPLARE ATTUALMENTE PIÙ GRANDE DI *PAGELLUS ERYTHRINUS* (SPARIDAE) RITROVATO NEL MAR TIRRENO (ITALIA)

SINTESI

L'articolo presenta un aggiornamento della dimensione massima di Pagellus erythrinus*, basato su un elenco completo di occorrenze georeferenziate aggiornato a gennaio 2026. Un esemplare eccezionalmente grande di* P. erythrinus *è stato catturato con una rete da posta commerciale a una profondità di 65 m su un fondale fangoso-roccioso al largo di Civitavecchia (Roma). L'esemplare misurava 660 mm di lunghezza totale e presentava un peso umido di 4.082 g. La specie è stata registrata in un ampio intervallo di profondità (1–300 m) in oltre venti località discontinue nell'oceano Atlantico e nel mar Mediterraneo tra il 1983 e il 2026. Lo studio conferma l'esemplare più grande di pagello fragolino finora documentato. La presente nota ittiologica fornisce un parametro chiave per gli studi sulla storia vitale e per la scienza della pesca.*

Parole chiave: pagello fragolino, lunghezza massima, peso massimo, Mediterraneo centrale

INTRODUCTION

The common pandora, *Pagellus erythrinus* (Linnaeus, 1758), is a benthopelagic, schooling marine fish that typically inhabits inshore waters with rocky, gravelly, muddy, or sandy substrates at depths between 40 and 200 m in the Mediterranean Sea (Golani *et al.*, 2006; Froese & Pauly, 2025). An omnivorous species, but mostly feeding on a large variety of benthic invertebrates and small fish (Bauchot & Hureau, 1986), *P. erythrinus* is protogynous hermaphroditic, in which sex change possibly occurs at a fork length (FL) between 12.8 and 20.3 cm FL (Froese & Pauly, 2025). While the species may exhibit two spawning periods in the southern Mediterranean, none have been reported in the Black Sea or northern European waters (Bauchot & Hureau, 1986).

P. erythrinus is distributed throughout the Mediterranean and is commonly encountered in the eastern Atlantic, from Brittany to the Cape Verde Islands, as well as around Madeira and the Canary Islands; it occurs less frequently in Scandinavia or off Mauritania (Bauchot & Hureau, 1986; Golani *et al.*, 2006) and is rare in the Black Sea. Published information on *P. erythrinus* in the Tyrrhenian Sea is limited, although the species plays an important role in the demersal fish community of the upper continental shelf, particularly in the southern area (10–100 m), with peak abundance between 10 and 50 m (Busalacchi *et al.* 2010, 2014).

The common pandora is a fish of commercial importance. While large quantities are captured by bottom trawls, the larger specimens are primarily caught using gillnets and trammel nets (Golani *et al.*, 2006), as well as bottom-set longlines (Vianson *et al.*, 2025).

This study reports an updated maximum size for *P. erythrinus*, based on the recent capture of an extraordinarily large specimen in the northern Tyrrhenian Sea, central Mediterranean.

MATERIAL AND METHODS

On 25 January 2026, an exceptionally large specimen of *Pagellus erythrinus* (Fig. 1) was captured in a commercial gillnet with a 40 mm mesh size, 12 miles off Civitavecchia (42°01′ N, 11°08′ E) at a depth of 65 m, on a muddy and rocky substrate (Fig. 2). The fish was immediately sold to a fishmonger in Rome (Famiglia Galluzzi – Pescheria dal 1894), who kindly photographed it alongside a tape measure and weighed it at our request. Morphometric measurements were recorded to the nearest millimetre, and weight was recorded in grams.

Fig. 1: An exceptionally large *Pagellus erythrinus* ***(660 mm TL; 4,082 g) caught off Civitavecchia, Tyrrhenian Sea (courtesy of Edoardo Galluzzi).***
Sl. 1: Izjemno velik *Pagellus erythrinus* ***(660 mm TL; 4,082 g), ulovljen pri Civitavecchii v Tirenskem morju (z dovoljenjem Edoarda Galluzzija).***

Fig. 2: Sampling site (yellow pin) of *Pagellus erythrinus* ***captured off Civitavecchia, Tyrrhenian Sea.***
Sl.2: Mesto vzorčenja (rumena značka) vrste *Pagellus erythrinus****, ujete ob Civitavecchii v Tirenskem morju.***

RESULTS AND DISCUSSION

The specimen was measured to the nearest millimetre and species identification followed Bauchot and Hureau (1986), Golani *et al*. (2006), and Froese & Pauly (2025). Morphometric measurements of *P. erythrinus* were estimated based on the tape measure placed alongside the fish in the photograph. The following percentages of TL were derived from the photographic scale: standard length, 84.1%; fork length, 89.8%; head length, 23.9%; pre-orbital length, 8.0%; pre-anal length, 52.3%; pre-pectoral length, 24.4%; pre-dorsal length, 32.6%; maximum body depth, 21.7%; and eye diameter, 4.1%.

Pagellus erythrinus typically reaches a maximum size of 60 cm TL, a common standard length (SL) of 20–25 cm, and the maximum published weight recorded for the species is 3,200 g (Bauchot & Hureau, 1986; Froese & Pauly, 2025). The specimen reported herein is considerably larger (660 mm TL and 4,082 g wet weight), surpassing all previously documented records. In fact, according to the data compiled in this study (see the size range column in Tab. 1), a specimen of this size has never been observed among the 30,717 specimens examined.

Records of the species, documented at depths ranging from 1 to 300 m and across more than twenty intermittent localities in the Atlantic and Mediterranean between 1983 and 2026 (see Tab. 1), indicate a population of a broad size range in this region. A review of the referenced studies in Table 1, along with the length–weight relationship data for the common pandora in FishBase, provides concrete size information. Accordingly, this study confirms the largest *P. erythrinus* specimen recorded to date.

Busalacchi *et al*. (2014) reported that in the southern Tyrrhenian Sea, *P. erythrinus* prefer the upper continental shelf (10–100 m depth). The capture depth in this study (65 m) falls within this range. While studies on the reasons for this preference are limited, it is generally observed that larger fish tend to inhabit deeper waters, with coastal fish often undergoing ontogenetic migrations towards these depths (Somarakis & Machias, 2002). The fact that the specimen was caught in a relatively deep area also supports this pattern. Setting aside its genetic makeup, the fish appears to have accessed the resources necessary for thriving in the wild. Its habitat may also have provided effective protection from predators, including fishermen.

Tab. 1: Successive records of *Pagellus erythrinus* ***throughout the Atlantic and Mediterranean Sea (BS: beach seine; GN: gillnet; LL: longline; T: trawl; TN: trammel net; TR: trap).***
Tab. 1: Zaporedni zapisi o vrsti *Pagellus erythrinus* ***po vsem Atlantiku in Sredozemskem morju (BS: obmorska potegalka; GN: zabodna mreža; LL: parangal; T: vlečna mreža; TN: trislojna mreža; TR: past).***

Sampling locations	Depth (m)	Method of detection*	Date	n	Size range (TL, mm)	References
Ionian Sea, Greece	?	T, BS	Jun. 1983-Apr. 1985	2710	43-322 FL	Papaconstantinou *et al*. (1988)
Cretan shelf, Greece	26-177	T	Aug. 1988-Apr. 1991	1190	50-230 FL	Somarakis & Machias (2002)
Canary Islands, Atlantic	12-136	TR, LL, T	Jan. 1991-Sep. 1993	957	75-371	Pajuelo & Lorenzo (1998)
SW coast of Portugal, Atlantic	?	GN, TN, LL	Aug. 1992-Dec. 1993	749	180-520	Gonçalves *et al*. (1997)
S. Tyrrhenian Sea, Italy	10-100	T	1994-2008	2166	55-480	Busalacchi *et al*. (2014)
S. Portuguese region, Atlantic	?	?	1995-2000	386	120-448	Coelho *et al*. (2010)
Algarve coast, Portugal	?	GN, TN, LL, T, TR	1998-2000	1075	130-357	Santos *et al*. (2002)
Edremit Bay, NE Aegean Sea	5-80	T	Nov. 1999-Oct. 2000	676	77-228 FL	Hoşsucu & Türker Çakır (2003)
Mersin Bay, NE Mediterran.	20-100	T	May 1999-Apr. 2000	1787	14-186	Cicek *et al*. (2006)
Izmir Bay, NE Aegean Sea	30-70	T	Jan. 2002-Jun. 2007	2654	62-278	Metin *et al*. (2011)
NW Sicily, Italy	10-200	T	Sum. 2004-Spr. 2005	2033	55-375	Giacalone *et al*. (2010)
Izmir Bay, NE Aegean Sea	30-70	T	Jun. 2005-May 2006	1014	65-269	Ilkyaz *et al*. (2008)
Adriatic Sea, Italy	?	T	2005-2006	1148	50-217	Stagioni *et al*. (2015)
Egyptian Mediterranean	?	T	Apr. 2007-May 2008	2670	60-300	Mehanna & Fattouh (2009)
Korinthiakos Gulf, Greece	50-300	GN, TN	Jun. 2008-Aug. 2009	773	108-380	Moutopoulos *et al*. (2013)
Catalan coast, France	1-80	?	Feb. 2007-Jul. 2010	717	135-580	Crec'hriou *et al*. (2013)
Egypt, E Mediterran.	?	T	Apr. 2008-Jul. 2010	1326	42-301	Mehanna & Farouk (2021)
Monastir Bay, Tunisia	?	?	Sep. 2011-Aug. 2012	640	110-300	Ali Ben Smida *et al*. (2014)
Gökova Bay, SE Aegean Sea	35-40	TN	Jan. 2016-Dec. 2016	945	59-302	Yapıcı & Filiz (2019)
Tripoli, Lebanon	4-90	LL, GN, BS	Feb. 2015-Dec. 2017	2152	75-400	Lteif *et al*. (2020)
Sicily, Italy	?	T	2012-2019	847	90-440	Falsone *et al*. (2022)
N. Sinai, Egypt	?	T	Jan.-Dec.2021	1512	110-279	Hegab *et al*. (2025)
W. Aegean Sea, Greece	?	T	2021-2024	589	109-340	Theocharis *et al*. (2025)
N. Tyrrhenian Sea, Italy	65	GN	25 Jan. 2026	1	660	Present study

Only two previous studies have reported specimens of the common pandora exceeding 500 mm TL: Gonçalves *et al.* (1997) recorded a *P. erythrinus* measuring 520 mm, while Crec'hriou *et al*. (2013) reported a specimen measuring 580 mm TL. The maximum age reported for *P. erythrinus* from otolith readings is 21 years (Abecasis *et al*., 2008; Coelho *et al*., 2010) for specimens measuring 400 mm and 448 mm TL, respectively. Although the exact ages of fish larger than 500 mm are currently unknown, it can be inferred that they likely far exceed 21 years.

In conclusion, maximum size is an important parameter in life history studies and fisheries science (Borges, 2001). This study suggests that *P. erythrinus* specimens in the northern Tyrrhenian Sea are larger than those reported from southwestern Portugal, the coasts of French Catalonia, and other Mediterranean populations. At present, and in the absence of reports suggesting otherwise, this appears to be unique among the world's seas.

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O POJAVLJANJU TRENUTNO NAJVEČJEGA EVIDENTIRANEGA PRIMERKA VRSTE *PAGELLUS ERYTHRINUS* (SPARIDAE) V TIRENSKEM MORJU (ITALIJA)

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POVZETEK

*Avtorja poročata o največjem zabeleženem primerku ribona (*Pagellus erythrinus*) na podlagi obsežnega seznama georeferenciranih pojavljanj te vrste do januarja 2026. Izjemno velik primerek vrste* P. erythrinus *je bil ujet s komercialno zabodno mrežo na globini 65 m na blatno-skalnem morskem dnu pri Civitavecchii (Rim). Ta primerek je meril v dolžino 660 mm in imel mokro težo 4.082 g. Vrsta je bila med letoma 1983 in 2026 zabeležena v širokem globinskem razponu (1–300 m) na več kot dvajsetih občasnih lokacijah v Atlantskem oceanu in Sredozemskem morju. Ta študija potrjuje največji doslej zabeleženi primerek vrste* P. erythrinus. *Ta ihtiološka beležka prispeva ključni parameter za študije življenjskega sloga in ribiško znanost.*

Ključne besede: ribon, maksimalna dolžina, maksimalna teža, osrednje Sredozemsko morje

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SUBSTANTIATED RECORD AND PRELIMINARY BIOLOGICAL INSIGHTS OF *MICROLIPOPHRYS DALMATINUS* (STEINDACHNER & KOLOMBATOVIĆ, 1883) FROM THE SEA OF MARMARA, TÜRKIYE

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ABSTRACT

This study reports the first evidence-based record of Microlipophrys dalmatinus *in the Sea of Marmara, Türkiye. Six specimens were collected using a beach seine between June and October 2024, at Çardak Lagoon in the Çanakkale Strait. The total lengths of the specimens ranged from 19.84 to 37.97 mm (mean: 29.8 ± 3.1 mm), and total weights ranged from 0.08 to 0.41 g (mean: 0.26 ± 0.05 g). The sample consisted of three juveniles collected from the lagoon inlet in August and October, and three ripening females (Stage III) collected from the inner lagoon in June. The current detection of* M. dalmatinus *in the Sea of Marmara may be either attributed to the species' cryptobenthic nature and small size, which may have led to it being historically overlooked, or to a recent range expansion driven by the species' thermophilic nature and rising seawater temperatures.*

Key words: Blenniidae, beach seine, coastal habitat, lagoons, morphometric characteristics

SEGNALAZIONE DOCUMENTATA E PRIME OSSERVAZIONI BIOLOGICHE SU *MICROLIPOPHRYS DALMATINUS* (FRANZ STEINDACHNER & JURAJ KOLOMBATOVIĆ, 1883) NEL MAR DI MARMARA, TURCHIA

SINTESI

Lo studio riporta la prima segnalazione documentata di Microlipophrys dalmatinus *nel Mar di Marmara, in Turchia. Sei esemplari sono stati catturati mediante sciabica da spiaggia tra giugno e ottobre 2024, presso la laguna di Çardak nello stretto dei Dardanelli. Le lunghezze totali degli esemplari variavano da 19,84 a 37,97 mm (media: 29,8 ± 3,1 mm), mentre i pesi totali variavano da 0,08 a 0,41 g (media: 0,26 ± 0,05 g). Il campione era composto da tre individui giovanili raccolti all'ingresso della laguna in agosto e ottobre, e tre femmine in maturazione (stadio III) raccolte nella laguna interna in giugno. L'attuale rilevamento di* M. dalmatinus *nel Mar di Marmara potrebbe essere attribuito sia alla natura criptobentonica e alle piccole dimensioni della specie, sia a una recente espansione dell'areale, favorita dal carattere termofilo della specie e dall'aumento delle temperature delle acque marine.*

Parole chiave: Blenniidae, sciabica da spiaggia, habitat costieri, lagune, caratteristiche morfometriche

INTRODUCTION

The family Blenniidae, commonly known as combtooth blennies, is one of the most diverse families of marine bony fishes currently comprising 59 genera and about 413 valid species worldwide (Fricke *et al.,* 2025). Despite their small size, these benthic fish play important ecological and biological roles in coastal marine environments, contributing to biodiversity and supporting coastal food webs (Patzner *et al.,* 2009). Combtooth blennies are primarily tropical and subtropical marine species, but they also occur rarely in freshwater and occasionally in brackish waters of the Atlantic, Indian, and Pacific Oceans (Patzner *et al.,* 2009; Nelson *et al.,* 2016).

In the Mediterranean Sea, direct research focusing specifically on combtooth blennies remains relatively limited. However, a few notable studies have provided valuable insights into their habitat preferences, ecological roles, and distribution patterns (*e.g.*, Orlando-Bonaca & Lipej, 2006; Tiralongo *et al*., 2016; Ergüden *et al*., 2024). Due to their small body size, specialized morphological and behavioral adaptations, and occurrence in habitats largely untargeted by commercial fishing gear, this group is considered ‘cryptobenthic.’ As specialized bottom-dwellers, combtooth blennies exhibit distinct morphological and ethological adaptations – such as specialized dentition and cryptic behavior – that enable them to occupy diverse ecological niches within the upper meters of Mediterranean rocky shores (Zander, 1972; Tiralongo *et al*., 2016). Despite their lack of commercial value, these species play a fundamental role in the functioning of coastal ecosystems, acting as both abundant predators and prey within the shallow infralittoral zone (Golani *et al*., 2014). Their distribution is often governed by fine-scale habitat requirements, including the availability of endolithic bivalve holes or photophilic algal covers, which provide essential shelter for their small bodies (Kotrschal, 1988; Lipej & Orlando-Bonaca, 2006).

Given the interspecies similarity in external morphology, the taxonomy of the family has undergone extensive revisions and reclassifications (Almada *et al.,* 2005). Consequently, over the past decade, researchers have increasingly relied on phylogenetic and biogeographic data to determine the distributional ranges of these species (Almada *et al.,* 2005; Levy *et al.,* 2011).

The genus *Microlipophrys* was first established by Almada *et al.* (2005) based on mitochondrial DNA and morphology of north-eastern Atlantic and Mediterranean blenniids, encompassing a total of seven species. Three species only occur in the tropical Atlantic (*Microlipophrys bauchotae, M. caboverdensis, M. velifer*), two are endemic to the Mediterranean Sea (*M. adriaticus, M. nigriceps*), and the remaining two (*M. canevae, M. dalmatinus*) have an Atlanto-Mediterranean distribution (Levy *et al.,* 2011).

Microlipophrys dalmatinus is one of four species of the genus recorded in Turkish waters, with occurrences reported from the northern Levant and Aegean Sea shores (Bilecenoğlu *et al.,* 2014; Bilecenoğlu, 2024). Due to its small size and peculiar habitat, this species is not captured by any commercial fishing gear and is seldom encountered during visual census surveys or snorkeling observation (Patzner *et al.,* 2009; Williams *et al.,* 2014). Consequently, available occurrence information might not reflect the actual distribution of the species. Until now, the presence of *M. dalmatinus* in the Sea of Marmara has been disputed, as previous records lacked essential taxonomic data needed to verify species identity (Bilecenoğlu, 2020). The only evidence suggesting its possible occurrence in the region comes from Kara and Yüksek (2023), who barcoded a single larva using 16S rRNA, but failed to obtain a COI sequence.

The present study provides the first substantiated record of *M. dalmatinus* in the Sea of Marmara, along with some of the biological data (including morphometric measurements and observations on reproductive biology) that are currently lacking for the species reported from the Mediterranean Sea.

MATERIAL AND METHODS

Sampling was conducted at seven coastal stations: at the lagoon inlet (BS1), outside the lagoon (BS2, BS3), and inside the lagoon (BS4, BS5, BS6, BS7) (Fig. 1). At each station, two hauls were performed using a beach seine deployed from a boat. Monthly sampling was carried out from May 2024 to April 2025, resulting in a total of 168 hauls.

The beach seine used in this study consisted of two 30 m-long wings, each 1.8 m in height and attached to a 15 m hauling rope. The net included a cod end (bag) measuring 2 × 2 × 2 m with a 4 mm mesh size, while the wings had larger, 6.5 mm meshes (Fig. 2). To ensure comprehensive ecological representation, the sampling gear was designed to be non-selective across all size cohorts.

The captured individuals were fixed in 4% formaldehyde and immediately transferred to the laboratory for species identification (Fig. 3). They were photographed and identified taxonomically based on morphological characteristics following Zander (1972) and Whitehead *et al*. (1984–1986).

Morphometric measurements were taken in millimeters (mm) using a digital caliper, and meristic characteristics were counted and recorded. Total weight and gonad weight were measured to the

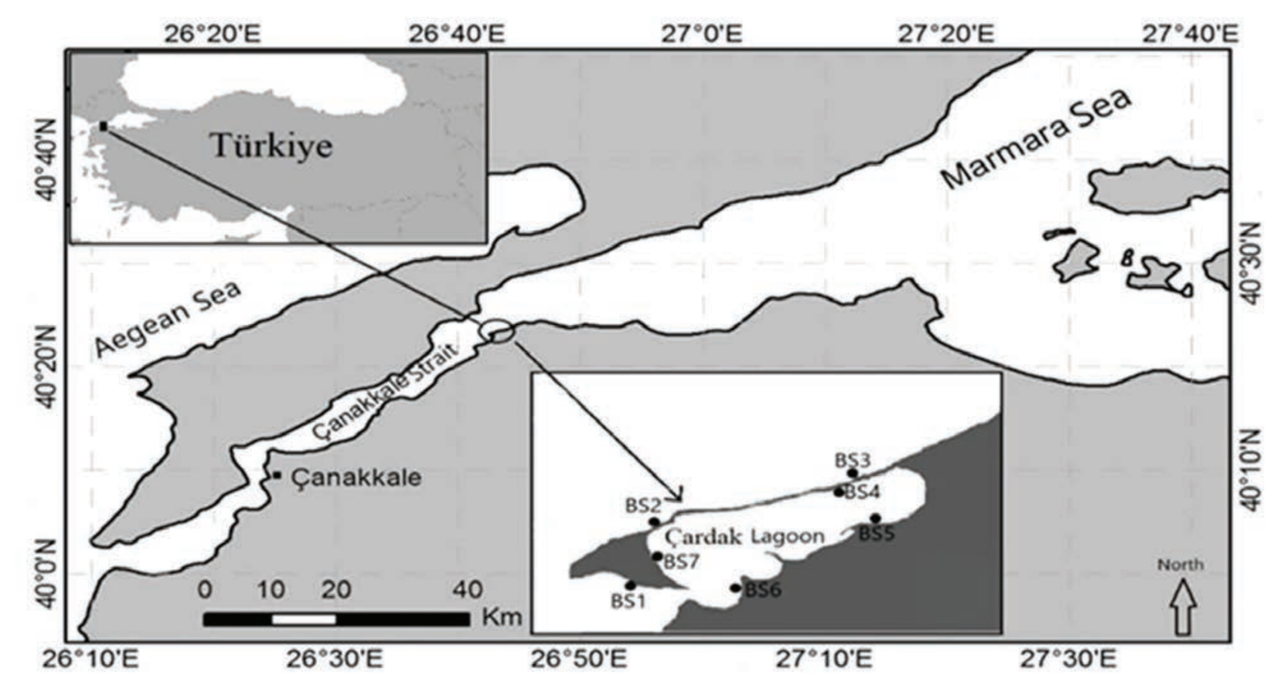

Fig. 1: Sampling locations of *M. dalmatinus* ***in the Çardak Lagoon, Sea of Marmara.***
Sl. 1: Lokacije vzorčenja vrste *M. dalmatinus* ***v laguni Çardak v Marmarskem morju.***

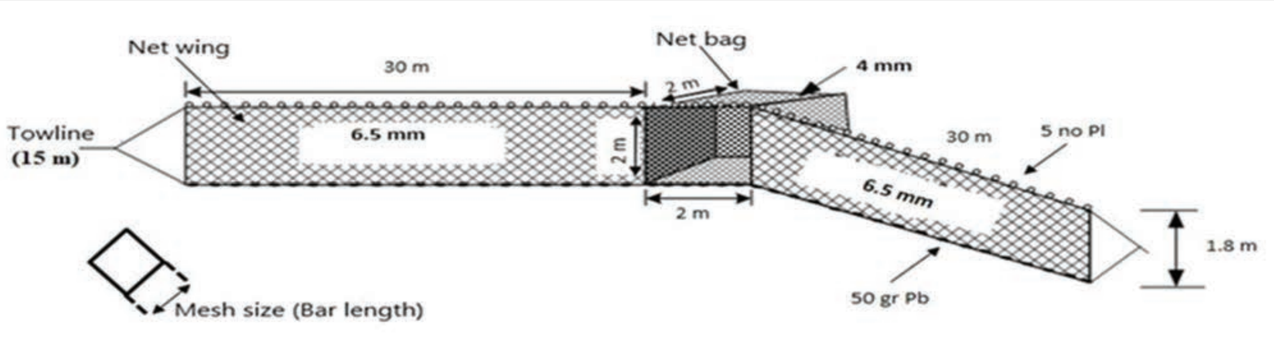

Fig. 2: Design and technical specifications of the beach seine net.
Sl. 2: Zasnova in tehnične specifikacije obmorske potegalke.

nearest 0.01 g. Specimens were subsequently dissected to determine sex and gonadal maturity stages through macroscopic examination of the gonads, with sexual maturity stages classified following Holden and Raitt (1974). Oocyte diameters were measured using a stereomicroscope in combination with the Q-Capture digital imaging program.

RESULTS

The sampled individuals were identified based on a combination of features: absence of supra-orbital tentacles, presence of a notch between spiny and soft part of dorsal fin, tip of pectorals not reaching level of the anus, and meristic counts of dorsal fin rays XII+16, anal fin rays II+18, pectoral fin rays 12, and pelvic fins I+3. All these traits perfectly match the descriptions of *M. dalmatinus*. Detailed morphometric measurements are presented in Table 1.

During the course of our study, a total of 164 individuals belonging to six Blenniidae species were sampled. In addition to *M. dalmatinus*, the species included *Salaria pavo*, *Parablennius gattorugine*, *P. sanguinolentus*, *P. tentacularis*, and *Lipophrys trigloides*, all of which have previously validated occurrences in the Sea of Marmara.

Tab. 1: Morphometric measurements and meristic counts of the six individuals of *Microlipophrys dalmatinus* ***sampled in this study. Each column represents a single specimen (n=6).***
Tab. 1: Morfometrične meritve in meristična štetja šestih primerkov vrste *Microlipophrys dalmatinus****, vzorčenih v tej raziskavi. Vsak stolpec predstavlja en primerek (n=6).***

Sampling time (2024)	**August**	**October**	**October**	**June**	**June**	**June**	
Location	**BS1**	**BS1**	**BS1**	**BS7**	**BS7**	**BS7**	
Specimen No.	**1**	**2**	**3**	**4**	**5**	**6**	**Mean ± SE**
Measurements (mm)							
Total length	19.89	28.53	19.84	37.97	36.37	35.96	29.8 ± 3.1
Standard length	16.96	24.49	16.15	32.93	31.88	31.4	25.6 ± 2.8
Body depth	5.63	5.45	4.51	8.74	7.94	7.73	6.7 ± 0.6
Eye diameter	1.25	1.64	1.41	1.5	1.38	1.27	1.4 ± 0.1
Preorbital length	1.05	1.79	1.29	2.47	2.18	2.15	1.8 ± 0.2
Interorbital length	1.37	1.06	1.05	1.2	1.02	1.01	1.1 ± 0.1
Head length	4.42	5.58	4.93	6.94	6.71	6.32	5.8 ± 0.4
Head width	2.62	3.16	3.07	4.72	3.88	3.73	3.5 ± 0.3
Mouth width	1.22	1.35	1.29	1.89	1.82	1.85	1.6 ± 0,1
Prepelvic length	4.07	4.53	4.43	5.69	5.53	6.42	5.1 ± 0.3
Predorsal length	3.92	6.21	4.62	7.2	6.95	6.82	6.0 ± 0.5
Preanal length	8.35	11.3	8.92	16.93	16.09	14.93	12.8 ± 1.4
Prepectoral length	4.47	5.62	4.84	8.7	6.82	6.73	6.2 ± 0.6
Postpelvic length	14.33	22.57	15.68	31.02	28.67	29.92	23.7 ± 2.7
Postdorsal length	3.5	5.13	3.95	7.39	6.79	6.9	5.6 ± 0.6
Postanal length	2.71	4.63	4.19	7.73	7.08	6.79	5.5 ± 0.7
Postpectoral length	11.67	16.58	11.84	21.19	20.41	18.71	16.7 ± 1.6
Dorsal fin base	11.81	17.2	11.94	23.07	21.1	21.02	17.7 ± 1.8
Anal fin base	3.9	11.8	7.92	14.67	14.11	12.82	10.9 ± 1.6
Pelvic fin length	2.12	4.45	2.52	4.73	3.91	4.55	3.7 ± 0.5
Pectoral fin length	4.55	5.91	5.11	8.02	7.25	7.12	6.3 ± 0.5
Caudal peduncule length	3.16	4.15	3.35	6.6	5.17	5.61	4.7 ± 0.5
Caudal peduncule height	2.41	2.98	2.57	4.17	3.53	5.24	3.5 ± 0.4
Total weight (g)	0.08	0.22	0.11	0.41	0.37	0.35	0.26 ± 0.05

Fig. 3: Sampled individuals of** M. dalmatinus **from Çardak Lagoon.
Sl. 3: Vzorčeni osebki vrste** M. dalmatinus **iz lagune Çardak.

Regarding *M. dalmatinus*, a total of three juvenile specimens were collected from the lagoon inlet: one in August 2024 and two in October 2024. An additional three specimens were collected from inside the lagoon in June 2024. Specimens ranged from 19.84 mm to 37.97 mm in total length, with a mean of 29.8 ± 3.1 mm (mean ± standard error). Individual weights ranged from 0.08 g to 0.41 g, with a mean of 0.26 ± 0.05 g (Tab. 1).

The gonadal development of females was classified as Stage III (ripening), based on the observation of ovaries occupying about two thirds of the body cavity. Their gonad weights were 0.0197 g, 0.0183 g, and 0.0073 g, respectively.

The number of mature oocytes was 88, 167, and 34 (Tab. 1). Diameters were measured for a total of 54 oocytes from these gonads. The minimum, maximum, and mean ± se of oocyte diameters were 0.39 mm, 0.69 mm, and 0.57 ± 0.009 mm, respectively (Fig. 4).

DISCUSSION

The documentation of *M. dalmatinus* in the Sea of Marmara addresses a long-standing ambiguity in the region’s ichthyofauna (Bilecenoğlu, 2020). However, a critical question remains: does this occurrence reflect a recent range expansion or a historical presence that has been systematically overlooked? We argue that the latter is more likely, primarily due to the cryptobenthic nature of the species and the historical lack of specialized scientific monitoring in the region’s littoral zones. In the Sea of Marmara, *M. dalmatinus* likely escapes capture by conventional commercial fishing gear, such as gillnets, trammel nets, purse seines, and beam trawls, which are not designed to sample such small benthic specimens. Furthermore, our study area – Çardak Lagoon – provides an ideal refuge, with a muddy substrate and dense algal cover, that may serve as a nursery for this species. As this is the first scientific study specifically focusing on the fish fauna of Çardak Lagoon and its surrounding waters, the confirmation of the occurrence of *M. dalmatinus* in the region may be attributed to the detailed coastal sampling methodology employed. Therefore, the perceived absence of this species in previous records may have resulted from the lack of scientific coastal sampling

Fig. 4: Oocyte maturation of *Microlipophrys dalmatinus*: ***Representation of Stage III (Ripening phase.)***
Sl. 4: Zorenje jajčnih celic vrste *Microlipophrys dalmatinus*: ***predstavitev III. stopnje (faza zorenja).***

surveys using non-selective beach seine nets and non-destructive visual census methods. While non-destructive visual censuses aided by SCUBA diving have become standard for monitoring Mediterranean blennies (Koppel, 1988; Lipej & Orlando-Bonaca, 2006), these techniques have significant limitations in lagoon environments such as Çardak. The high turbidity and sedimentation levels often observed in these areas can severely reduce visibility, making the detection of small, cryptobenthic species like *M. dalmatinus* extremely challenging for divers. Furthermore, the secretive behavior of this species – often burrowing or hiding within dense algal mats – necessitates more direct sampling approaches. In this regard, the use of specifically designed, non-selective sampling gear provided a more reliable alternative to visual methods, allowing the capture of individuals that would otherwise have remained inconspicuous in turbid lagoon waters.

While the secretive ecology of the species likely played a major role in its delayed detection, the potential influence of changing environmental conditions on its northward distribution should also be considered. The northward extension of several thermophilic native species in the Mediterranean Sea, primarily as a result of seawater warming, is an ongoing trend (Bianchi *et al.,* 2018), and *M. dalmatinus* is known for its affinity for warm-temperate conditions (Levy *et al.*, 2011). Mean surface water temperatures in the Sea of Marmara have increased by approximately 1.4 °C since the early 1970s (Bilecenoğlu & Öztürk 2019), which may have facilitated the penetration of this species from the Aegean Sea along the prevailing bottom flow layer.

Only six specimens of *M. dalmatinus* were obtained from 168 beach seine samplings, revealing the species' conspicuous rarity and low abundance. Despite the limited sample size, which is a direct consequence of the species' elusive nature, these specimens allow preliminary observations regarding the biological characteristics of *M. dalmatinus* in the Sea of Marmara. While these findings should be interpreted with caution due to the small number of individuals, they provide initial insights into life-history traits of the species that have remained largely undocumented in this region. Specifically, the presence of both mature females and juveniles across different months suggests a potential reproductive cycle, although further extensive sampling is necessary to fully characterize the species population dynamics and spawning phenology in the area. The occurrence of mature female *M. dalmatinus* in June suggests that Çardak Lagoon may serve as a potential spawning ground for the species. Furthermore, the occurrence of juveniles at the lagoon inlet just two months after the presumed spawning period (between August and October) indicates that the area may also function as a nursery habitat. These observations are consistent with Zander (1986), who reported a reproductive period extending from May to July. Similarly, Verdiell-Cubedo *et al*. (2006) recorded 68 individuals of *M. dalmatinus* in the Mar Menor lagoon, Spain. Furthermore, our observations align with Patzner *et al*. (2009) and Nelson *et al*. (2016) regarding the species' preference for brackish-water habitats. Thus, the lagoon and its adjacent waters may provide a vital environment for Blenniidae species.

Returning to the species' characteristics, *M. dalmatinus* is relatively small-bodied (Patzner *et al.,* 2009). While Zander (1986) reported a maximum total length (TL) of 41 mm, subsequent studies documented variations, including a TL of 32 mm in Malta (Falzon, 2009) and a wider range of 16–58 mm in the Mar Menor coastal lagoon, Spain (Verdiell-Cubedo *et al.,* 2006). The total lengths recorded in the present study (19.9–37.9 mm) are consistent with these established size ranges. Notably, morphometric measurements for this species had not been documented in the literature prior to this study. Our meristic counts align with Zander (1986), further confirming the clear morphological differentiation of *M. dalmatinus* from its congeners within the genus Microlipophrys. Furthermore, this study provides the first formal data on sexual maturity and oocyte development, including detailed measurements of oocyte diameter.

CONCLUSIONS

Water pollution, eutrophication, and the deterioration of water quality can negatively affect the survival rates and habitat of Blenniidae species (Vinyoles & De Sostoa, 2007; Laportea *et al.,* 2014). Reports show that Çardak Lagoon has been affected by similar adverse impacts (Ateş *et al.,* 2023; İşcan *et al.,* 2025). Our findings demonstrate that the use of a specifically designed, non-selective beach seine is an effective and advantageous method for documenting cryptobenthic assemblages in turbid lagoon environments where visual censuses and conventional sampling gear may fail.

This study provides the first material-based record of *M. dalmatinus* in the Sea of Marmara, highlighting the critical role of Çardak Lagoon as a potential spawning habitat, and establishing an important baseline the for conservation and monitoring of this ecologically significant species in the face of anthropogenic threats.

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POTRJEN ZAPIS O POJAVLJANJU IN PREDHODNA BIOLOŠKA SPOZNANJA O VRSTI *MICROLIPOPHRYS DALMATINUS* (STEINDACHNER & KOLOMBATOVIĆ, 1883) IZ MARMARSKEGA MORJA, TURČIJA

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POVZETEK

Avtorja poročata o prvem z dokazi podprtem zapisu o pojavljanju dalmatinske babice (Microlipophrys dalmatinus*) v Marmarskem morju v Turčiji. Z obmorsko potegalko so med junijem in oktobrom 2024 ujeli šest primerkov v laguni Çardak v ožini Çanakkale. Totalne dolžine primerkov so bile med 19,84 in 37,97 mm (povprečno 29,8 ± 3,1 mm), celokupne mase pa med 0,08 in to 0,41 g (povprečno 0,26 ± 0,05 g). Tri primerki, odvzeti iz vhoda v laguno avgusta in oktobra, so bili mladostni, drugi trije so bile dozorevajoče samice (III. faza), vzorčene v notranji laguni junija. Trenutno najdbo vrste* M. dalmatinus *v Marmarskem morju je mogoče pripisati bodisi kriptobentoški naravi in majhnosti vrste, zaradi česar je bila morda v preteklosti spregledana, bodisi nedavni širitvi območja razširjenosti, ki sta jo sprožili termofilna narava vrste in naraščajoče temperature morske vode.*

Ključne besede: Blenniidae, obmorska potegalka, obrežni habitat, lagune, morfometrični znaki

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POPULATION STUDY OF *TRACHURUS MEDITERRANEUS* FOCUSED ON REPRODUCTIVE BIOLOGY IN EDREMIT BAY, NORTHERN AEGEAN SEA

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ABSTRACT

This study provides insights into the reproductive traits of 754 individuals of Trachurus mediterraneus *collected in Edremit Bay between September 2008 and August 2009. The overall sex ratio differed significantly from the expected 1:1 ratio. Length at first sexual maturity (L_{50}) in females was 18.6 cm. Macroscopic examination of gonads and gonadosomatic index analyses indicated that the spawning period extended from March to August, with peak activity in April. Fulton's condition factor and the gonadosomatic index values showed inverse variation throughout the study period. Total fecundity ranged from 2,738 to 48,315 oocytes and showed strong positive correlations with total length and total weight. These findings provide essential information on the reproductive biology of this economically important species and may contribute to the sustainable management of its populations in the Aegean Sea.*

Key words: *Trachurus mediterraneus*, spawning, fecundity, Edremit Bay

STUDIO SULLA POPOLAZIONE DI *TRACHURUS MEDITERRANEUS,* CON PARTICOLARE ATTENZIONE ALLA BIOLOGIA RIPRODUTTIVA, NELLA BAIA DI EDREMIT, MAR EGEO SETTENTRIONALE

SINTESI

Lo studio fornisce approfondimenti sulle caratteristiche riproduttive di 754 individui di Trachurus mediterraneus *catturati nella baia di Edremit tra settembre 2008 e agosto 2009. Il rapporto complessivo tra i sessi differiva significativamente dal rapporto atteso di 1:1. La lunghezza alla prima maturità sessuale (L50) nelle femmine era di 18,6 cm. L'esame macroscopico delle gonadi e le analisi dell'indice gonadosomatico indicano che il periodo di deposizione si* **è** *esteso da marzo ad agosto, con un picco in aprile. Il fattore di condizione di Fulton e i valori dell'indice gonadosomatico hanno mostrato una variazione inversa durante l'intero periodo di studio. La fecondità totale variava da 2.738 a 48.315 ovociti e mostrava forti correlazioni positive con la lunghezza totale e il peso totale. I risultati forniscono informazioni essenziali sulla biologia riproduttiva della specie e contribuiscono alla gestione sostenibile delle sue popolazioni nell'Egeo.*

Parole chiave: *Trachurus mediterraneus,* deposizione, fecondità, Baia di Edremit

INTRODUCTION

Biological characteristics related to reproduction such as sex ratio, size at first sexual maturity, spawning period, fecundity, and condition factor are key parameters for the effective management of fishery resources (Komolafe & Arawomo, 2007). Understanding the size at which individuals first reach sexual maturity and the timing of the spawning season is critical for determining appropriate minimum catch sizes and for implementing fishing restrictions or seasonal bans (Dinh, 2018). Among these traits, fecundity holds particular significance in fish biology, as it may provide insight into fluctuations in population biomass (Das *et al.*, 1989). Reproductive studies in fishery science have traditionally focused on female specimens, largely because reproductive output is more strongly constrained by egg production than by sperm availability (Helfman *et al.*, 1997).

The Mediterranean horse mackerel (*Trachurus mediterraneus*) is a carnivorous species distributed across the Mediterranean and Black Seas, as well as the eastern Atlantic coastline from the English Channel to the waters off Morocco (Smith-Vaniz, 1987). This marine and brackish pelagic species, typically occurring at depths ranging from 20 to 200 meters, is known to form schools and exhibit oceanodromous migratory behaviour (Riede, 2004). Numerous studies have addressed its biological characteristics in different regions, including Egypt (El-Gharabawy & Abdel-Aziz, 1988), Tunisia (Ben Salem & Ktari, 1992), Türkiye (Bayhan & Mater, 2000; Şahin *et al.*, 2009; Demirel & Yüksek, 2013), Bulgaria (Yankova *et al.*, 2009, 2010), and the Adriatic Sea (Jardas *et al.*, 2004; Šantić *et al.*, 2006, 2011).

Edremit Bay, Türkiye, is a convergence zone influenced by regional circulation and interaction of Mediterranean and Black Sea-derived water masses, making it an important nursery area for both pelagic and demersal species (Toğulga, 1997). Although *T. mediterraneus* is among the economically important species in the region, no detailed studies have been conducted in Turkish waters, with the exception of Demirel & Yüksek (2013). Therefore, this study represents the first comprehensive investigation of reproductive parameters such as sex ratio, spawning season, size at first maturity, and fecundity, in Edremit Bay, northern Aegean Sea.

MATERIAL AND METHODS

A total of 754 specimens of Mediterranean horse mackerel were obtained from commercial catches between September 2008 and August 2009 in Edremit Bay (26º57′–26º34′E, 39º17′–39º34′N). From each monthly catch, a random subsample of 49 to 72 individuals (average: 62) was selected to ensure unbiased representation and consistent temporal coverage throughout the study period. During the study period, water temperature, pH, and salinity were measured monthly using a Hach HQ40d multiparameter device. Species identification was based on diagnostic morphological traits, including eye diameter, length of the accessory lateral line, and height of lateral line scales (Bini, 1968; Fischer *et al.*, 1987) (Fig. 1). Since the specimens were obtained from commercial fisheries without any experimental manipulation, ethical approval was not required.

Total fish length (TL) was measured to the nearest 0.1 cm, from the anterior tip of the longest jaw to the posterior end of the caudal fin, using a digital calliper. Total weight (TW) was recorded to the nearest 0.01 g using an electronic balance. Sex was determined in all individuals by macroscopic examination of the gonads and classified based on the maturity scale defined by Holden & Raitt (1974).

Sex ratio was calculated as the ratio of females to males, monthly. Differences between the observed and expected proportions of females and males were tested using the chi-square (χ^2) formula:

$\chi^2 = \sum (O-E)^2/E$,

where:

χ^2 = Chi-square statistic

O = observed values

E = expected values

The null hypothesis (H_0), stating that there is no difference between the proportions of females and males, was tested at a significance level of $p < 0.05$ (Zar, 1996).

The gonadosomatic index (GSI) was calculated according to the equation:

$GSI = (GW/SW) \times 100$

where GW is gonad weight and SW is somatic weight (gonad free-weight) of the specimens, both recorded in grams (Avşar, 2016).

Fulton's condition factor (CF) was calculated separately for each sex as:

$CF = (TW/ TL^3) \times 100$, where TW is total weight (g) and TL is total length (cm) (Sparre & Venema, 1992).

The spawning period was determined based on the occurrence of gonads in mature stages (III and IV) and analyses of monthly variation in maturity-stage proportions and GSI values. In addition, the monthly percentages of each maturity stage were calculated.

Length at 50% maturity (L_{50}) was estimated by fitting maturity ogives using a log-logistic (Gompertz-type) model. The proportion of mature individuals (stages III–V) relative to immature ones (stages I–II) was calculated within 1-cm TL intervals, separately for each sex during the reproductive period. L_{50} was estimated based on the double-log function described by Ilkyaz *et al.* (1998). The equations applied were:

$r(TL) = \exp[-\exp(-(a + bTL))]$

$L_{50} = [-\ln(-\ln(0.5)) - a] / b$

where r(TL) is the proportion of mature individuals at a given TL, L_{50} is the estimated length at which 50% of individuals are mature, and *a* and *b* are the intercept and slope of the function, respectively. Although logistic regression is commonly used for maturity estimation, this

Fig. 1: General appearance of *T. mediterraneus* ***(Photo: Gülçin Ulunehir Aydın).***
Sl. 1: Splošni videz vrste *T. mediterraneus* ***(Foto: Gülçin Ulunehir Aydın).***

approach was chosen due to its robust fit to the observed data and its frequent use in regional studies.

Total fecundity, defined as the total number of mature oocytes ready for spawning within a single reproductive cycle, was estimated for 169 mature female specimens using the gravimetric method (Bagenal & Tesch, 1978; Bithy *et al.*, 2012). To account for potential variability within the ovary, oocytes were randomly sampled from three regions of the ovarian lobes: anterior, middle, and posterior. Each subsample was carefully dissected, and oocytes were separated individually using fine needles under a stereomicroscope to ensure accurate counting. The number of oocytes in each subsample was counted, and fecundity for each subsample was subsequently calculated using the following formula (Karlou-Riga & Economidis, 1997):

$F_s = (n \times GW) / w$

where:

F_s= fecundity of subsample

n = number of oocytes in subsample

GW = gonad weight

w = weight of subsample

Total fecundity (F) for each fish was calculated by averaging fecundity estimates obtained from the three subsamples, as expressed by:

$F = (F_1 + F_2 + F_3) / 3$

where F_1, F_2, and F_3 represent fecundity estimates from the anterior, middle, and posterior ovarian regions, respectively. This approach ensures a representative estimate of total fecundity, reflecting the reproductive potential of individual females during the spawning season.

Regression analysis was used to evaluate the relationships between total fecundity (F) and both total length (TL) and total weight (TW) in female fish. A linear regression model was applied to describe the relationship between fecundity and total weight, while a power function model ($F = a \times TL^b$) was used for the fecundity–length relationship. Model performance was evaluated using the coefficient of determination (R^2) to assess the strength of the relationships between variables. Among several tested models (including linear, logarithmic, exponential, and power functions), the selected models were those providing the best fit based on R^2 values and visual inspection of residuals. All statistical analyses were conducted using Jamovi 1.6.23, Microsoft Excel 2013, and PAST 4.03.

RESULTS

The present study focused on the reproductive biology of Mediterranean horse mackerel from Edremit Bay. Length–frequency distributions for females, males, and the combined sample are presented in Figure 2. Female total lengths ranged from 11.15 to 34.9 cm, male total lengths from 11.19 to 34.9 cm, and overall total lengths from 11.15 to 34.9 cm. No statistically significant differences were observed between females and males with respect to mean total length and mean total weight (*t*-test, $p > 0.05$).

A total of 754 specimens, including 323 males and 431 females, were collected during the study period. The overall sex ratio deviated significantly from the expected 1:1 proportion (F:M = 1.33:1; $\chi^2 = 15.46$; $p < 0.05$). Monthly variation of sex ratio is shown in Figure 3. Females generally predominated throughout the study period, except in September, when males were more abundant. Statistically significant deviations from the expected 1:1 sex ratio were observed only in March (F:M = 2.44:1; $\chi 2 = 9.62$; $p < 0.05$), October (F:M = 2.13:1; $\chi 2 = 9.72$; $p < 0.05$) and November (F:M = 1.62:1; $\chi 2 = 4.26$; $p < 0.05$).

The monthly variation in maturity stages is presented in Figure 4. While stages III, IV, and early stage V, as well as the sex of each specimen, were readily determined, identification of stages I, II, and late stage V proved more

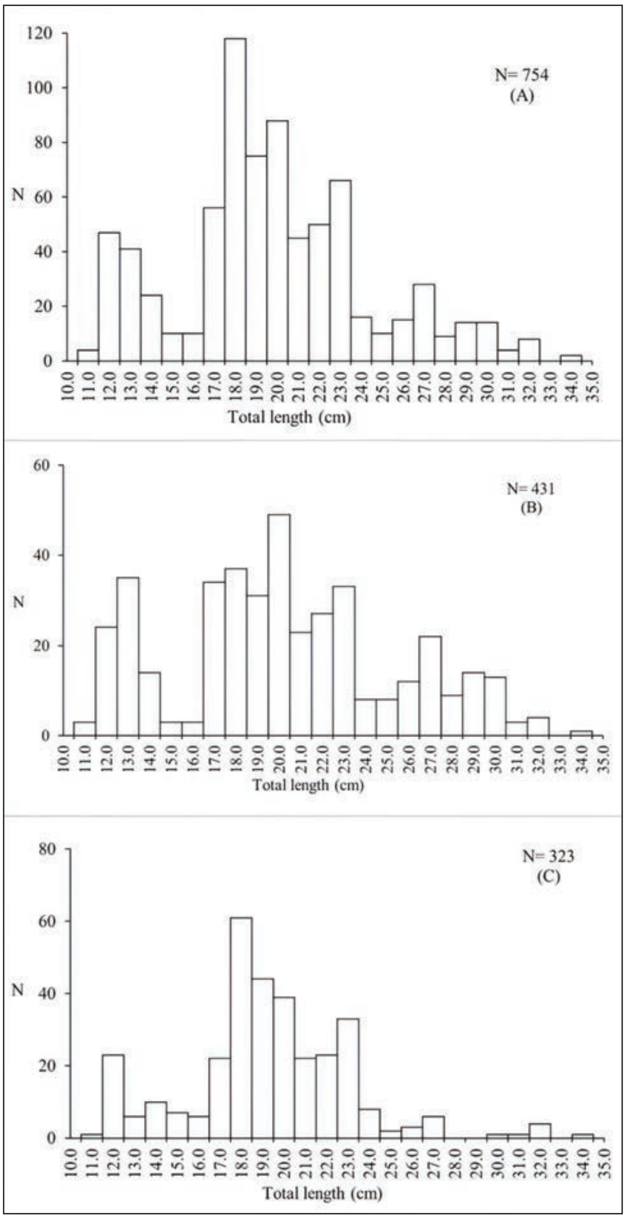


Fig. 2: Total length–frequency distribution of all individuals (A), females (B), and males (C) for *T. mediterraneus* **in Edremit Bay.**
Sl. 2: Velikostna porazdelitev vseh osebkov (A), samic (B) in samcev vrste *T. mediterraneus* **v Edremitskem zalivu.**

difficult. In these stages, the gonads were very small, and the distinction between male and female gonads could not be reliably determined.

The size at which 50% of the female *T. mediterraneus* population reached sexual maturity (L_{50}) was calculated as 18.6 cm using on a Gompertz-type model (Fig. 5).

The gonadosomatic index (GSI) revealed that the reproductive season extended from March to August, peaking in April (Fig. 6). The highest mean female GSI value (%) was recorded in April (4.112%), the lowest in August (0.375%). Differences in monthly GSI values were statistically significant (d.f.: 11,742; F = 103.835; $p < 0.001$; one-way ANOVA). During the same period, sea surface temperature exhibited a seasonal increase, from 14.0 °C in winter to 22.5 °C in summer. Dissolved oxygen concentrations were highest in winter and early spring (11.5–12.6 mg L^{-1}) and decreased during summer (7.1–7.5 mg L^{-1}). Salinity remained relatively stable throughout the study period, varying within a narrow range of 36.0 to 39.0‰ (Fig. 6).

As shown in Figure 7, the highest and lowest average monthly CF values for females were found in July (1.203) and March (0.883), respectively. Similarly, the highest and lowest average monthly CF values for males were observed in August (1.309) and April (0.818),

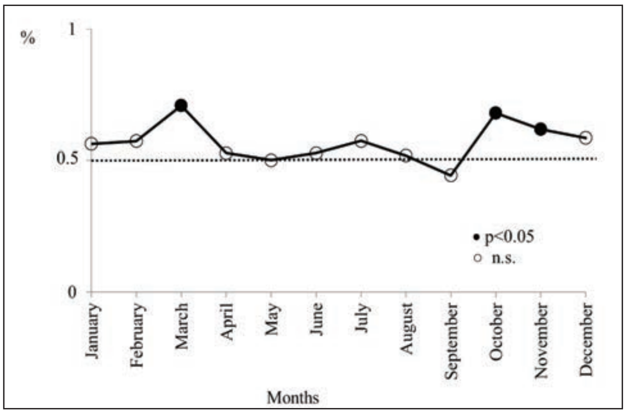


Fig. 3: Monthly sex ratio of T. mediterraneus (• statistically significant deviation from the 1:1 ratio, ∘ not significant) in Edremit Bay.
Sl. 3: Mesečno razmerje med spoloma pri vrsti T. mediterraneus (• statistično značilno odstopanje od razmerja 1:1, ∘ ni značilno) v Edremitskem zalivu.

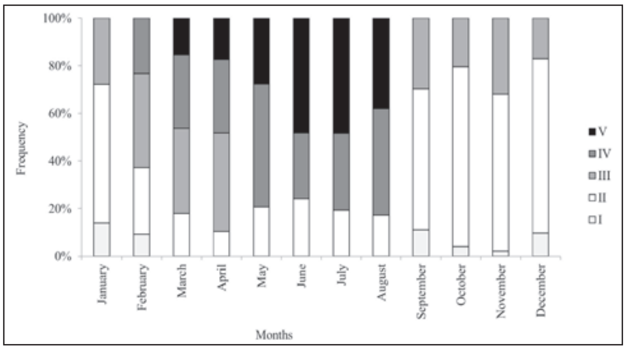


Fig. 4: Monthly percentage distribution of maturity stages of female *T. mediterraneus* **in Edremit Bay.**
Sl. 4: Mesečna porazdelitev razvojnih stopenj pri samicah vrste *T. mediterraneus* **v Edremitskem zalivu (v odstotkih).**

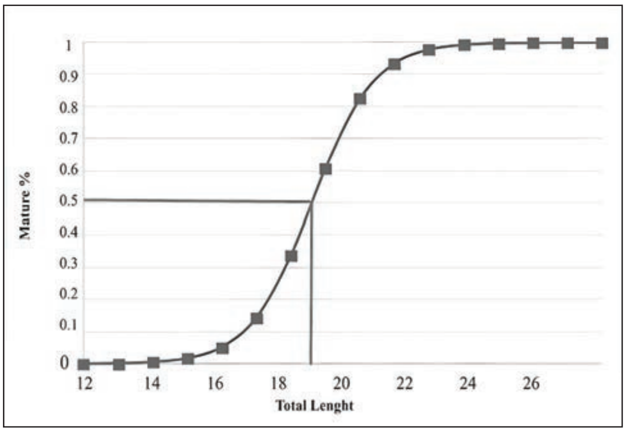
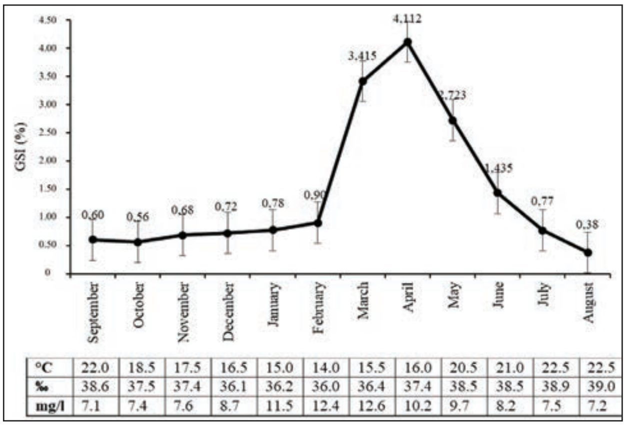


Fig. 5: Length at first sexual maturity of female T. mediterraneus in Edremit Bay.
Sl. 5: Dolžina ob prvi spolni zrelosti pri samicah vrste T. mediterraneus v Edremitskem zalivu.



°C	22.0	18.5	17.5	16.5	15.0	14.0	15.5	16.0	20.5	21.0	22.5	22.5
‰	38.6	37.5	37.4	36.1	36.2	36.0	36.4	37.4	38.5	38.5	38.9	39.0
mg/l	7.1	7.4	7.6	8.7	11.5	12.4	12.6	10.2	9.7	8.2	7.5	7.2

Fig. 6: Monthly variation in gonadosomatic index of female *T. mediterraneus* ***in Edremit Bay, along with monthly mean sea surface temperature, salinity, and levels of dissolved oxygen.***
Sl. 6: Mesečno spreminjanje gonadosomatskega indeksa pri samicah vrste *T. mediterraneus* ***v Edremitskem zalivu, skupaj s povprečno mesečno površinsko temperaturo morja, slanostjo in nivoji raztopljenega kisika.***

respectively. Differences between monthly CF values were statistically significant (d.f.: 11,742; F: 7.956; $p < 0.001$; one-way ANOVA).

Total fecundity of T. mediterraneus ranged from 2,738 eggs (TL = 12.1 cm, TW = 22.29 g) to 48,315 eggs (TL = 32.9 cm, TW = 245.78 g). The results indicated a significant positive relationship between total fecundity and both total length and total weight in mature females (Fig. 8). The relationships were described by the following equations: $F = 151.05 \times TW + 4919.8$ ($R^2 = 0.9796$); $F = 6.005 \times TL^2.63$ ($R^2 = 0.9255$). These findings indicate a strong size-dependent increase in fecundity.

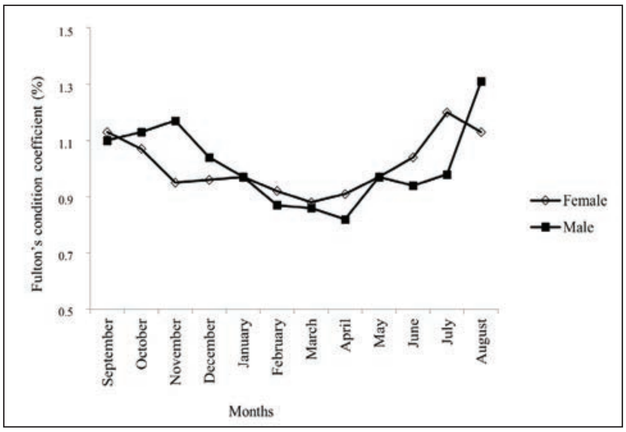


Fig. 7: Monthly variation in Fulton's condition factor of female and male *T. mediterraneus* ***in Edremit Bay.***
Sl. 7: Mesečna dinamika Fultonovega indeksa kondicije pri samicah in samcih vrste *T. mediterraneus* ***v Edremitskem zalivu.***

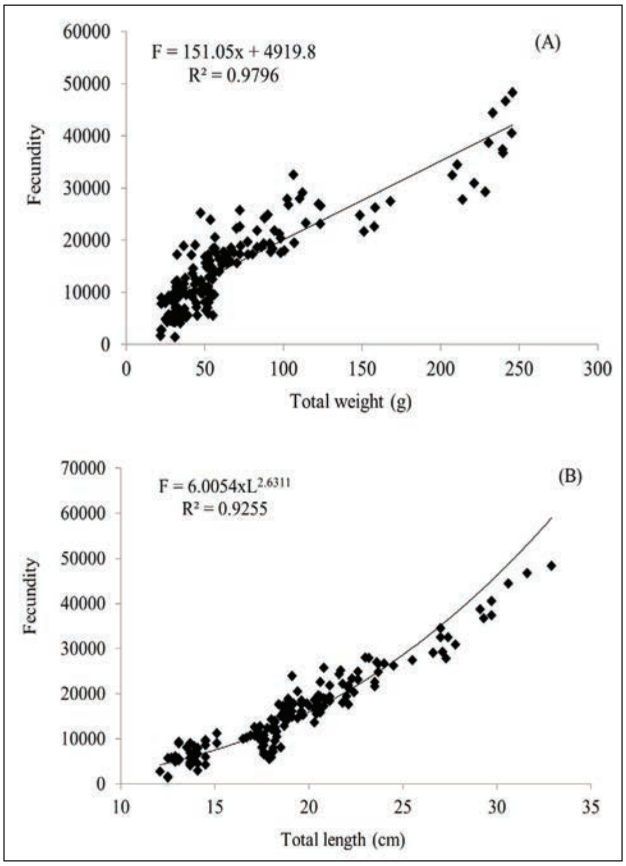


Fig. 8: Relationships between total fecundity and total weight (A) and total length (B) in female T. mediterraneus in Edremit Bay.
Sl. 8: Razmerje med celotno plodnostjo in celokupno maso (A) ter totalno dolžino (B) pri samicah vrste T. mediterraneus v Edremitskem zalivu.

DISCUSSION

This study provides the first comprehensive data on the reproductive biology of *T. mediterraneus* in Edremit Bay, establishing fundamental biological parameters for population assessment and management. A total of 754 specimens of were examined. Length–frequency distributions are presented in Figure 1, with TL ranging from 11.5 to 34.9 cm in females, 11.9 to 34.9 cm in males, and 11.5 to 34.9 cm for all individuals combined. As shown in Table 1, the size range observed in the present study generally differs from those reported for several other regions. However, comparable size distributions have been documented in the Adriatic Sea (Viette *et al.*, 1997; Jardas *et al.*, 2004; Šantić *et al.*, 2006, 2011; Pešić *et al.*, 2012). These variations in size may be attributed to environmental factors such as temperature, organic matter availability, feeding regime, capture time, stomach fullness, disease status, and parasitic burden (Ahamed *et al.*, 2018).

The sex ratio (F:M) in the present study was skewed in favour of females (1.33:1) throughout the study period, except in September (Fig. 2). Although the sex ratio in most fish species is typically close to 1:1, it may vary among species and populations of the same species, and fluctuate temporally within a population (Nikolsky, 1980). As indicated in Table 1, the predominance of females observed in the present study is consistent with findings from previous studies on T. mediterraneus populations, including those from the Adriatic and Black Seas (Jardas *et al.*, 2004; Šantić *et al.*, 2006, 2011; Pešić *et al.*, 2012; Yankova *et al.*, 2009; Demirel & Yüksek, 2013). This female dominance has been attributed to factors such as longer lifespan in females, earlier and more readily identifiable ovarian development compared to testes, and sex-specific migratory behaviour (Khemiri & Gaamour, 2009).

Mature females (stages III–V) were observed throughout the year, suggesting a prolonged spawning period for Trachurus mediterraneus in Edremit Bay (Fig. 3). This reproductive strategy enhances annual egg production (Burt *et al.*, 1988) while also reducing susceptibility to fishing pressure (Lowerre-Barbieri *et al.*, 1998). Given these advantages, accurate estimation of size at first sexual maturity (L_{50}) is essential for effective stock management. In the present study, L_{50} for female T. mediterraneus in Edremit Bay was estimated at 18.6 cm TL (Fig. 4). This value, while higher than recent estimates reported for the western Mediterranean (13.8–17.7 cm TL; Rodríguez-Castañeda *et al.*, 2022), falls within the broader range documented for Mediterranean populations (15.7–22.5 cm TL; Ragonese *et al.*, 2002; Samia *et al.*, 2002), indicating marked intraspecific variability (Table 2). Notably, the L_{50} estimated for Edremit Bay is substantially higher than values reported from the Sea of Marmara (12.2–12.5 cm TL; Demirel & Yüksek, 2013), a semi-enclosed basin characterised by restricted water exchange and distinct hydrographic conditions that may promote earlier sexual maturation at smaller body sizes. In contrast, the more open and stable environmental conditions in Edremit Bay, including higher winter temperatures and elevated levels of dissolved oxygen, likely support sustained somatic growth and delayed maturation, resulting in sexual maturity at larger body sizes.

Judging from gonadosomatic index (GSI) values and maturity stage analyses (Figs. 3 and 5), spawning of Trachurus mediterraneus in Edremit Bay occurs between March and August, with a pronounced peak in April. This spawning period is generally consistent with those reported from several other Mediterranean regions, whereas studies conducted in the Black Sea and the Marmara–Black Sea transition zone indicate a shorter and temporally shifted reproductive season (*e.g.*, Demirel & Yüksek, 2013; Tab. 3). These differences suggest that the onset, duration, and termination of the reproductive period in *T. mediterraneus* may vary geographically in response to local environmental conditions. As noted by Nikolsky (1980), reproductive timing in fish populations is influenced by multiple environmental factors, including hydrological regime, temperature, and food availability. In this context, the earlier onset and longer duration of the spawning period observed in Edremit Bay likely reflect favourable environmental conditions in the northern Aegean Sea. In particular, relatively high levels of dissolved oxygen recorded between January and April coincide with the pre-spawning and early spawning phases, suggesting enhanced physiological readiness for reproduction. Together with the progressive increase in seawater surface temperature, these conditions are likely to improve feeding efficiency and energy allocation toward gonadal development, thereby promoting earlier onset and prolonged reproductive activity, as reflected in elevated GSI values.

The calculated monthly condition factor (CF) values for the Mediterranean horse mackerel are presented in Figure 6. CF is an index reflecting the combined effects of biotic and abiotic factors on the physiological condition of fish. It is generally correlated with monthly variations in gonadosomatic index (GSI) (Avşar, 2016). As shown in Figures 5 and 6, CF increased from April onwards, peaking in July and August, which indicates an inverse relationship with GSI. Lower CF values coincided with higher GSI values, suggesting that CF may reflect reproductive activity in T. mediterraneus in Edremit Bay.

In this study, total fecundity was found ranging from 2,738 to 48,315 eggs in fish with total lengths between 12.1 and 32.9 cm and total weights between 22.29 and 245.78 g. These results differ from those of previous studies that estimated batch fecundity (*i.e.*, the number of eggs released per spawning event). Pora (1979) reported batch fecundity values ranging from 2,369 to 46,200 eggs in fish with fork lengths of 11.8 to 19.5 cm from the Black Sea. Similarly, Demirel & Yüksek (2013) reported batch fecundity values between 1,058 and 28,116 eggs

Tab. 1: Total length, total weight, and sex ratios of** Trachurus mediterraneus **in the present and previous studies.
Tab. 1: Totalna dolžina, celokupna masa in razmerja med spoloma pri vrsti** Trachurus mediterraneus **v pričujoči in predhodnih raziskavah.

Reference	**N**	**TL (cm)**	**TW (g)**	**(F:M)**	**Locality**
Viette *et al.* (1997)	482	9.8-38.3	-	-	Adriatic Sea
Merella *et al.* (1997)	232	3.9-24.4	-	-	Balear Islands
Karlou-Riga (2000)	1325	5.6-39.3	-	1.00:1	Aegean Sea
Moutopoulos & Stergiou (2002)	191	17.3-34.1	-	-	Aegean Sea
Koutrakis & Tsikliras (2003)	21	11.7-25.7			Aegean Sea
Jardas *et al.* (2004)	237	11.7-36.8	-	1.04:1	Adriatic Sea
Šantić *et al.* (2006)	1245	14.8-39.1	20.6-485.1	1.05:1	Adriatic Sea
Karakulak *et al.* (2006)	31	14.2-26.6	-	-	Aegean Sea
Sangun *et al.* (2007)	373	7.0-19.1	2.46-60.59	-	Mediterranean
Cherif *et al.* (2007)	182	8.8-30.0	-	-	Tunisia
Bostancı (2009)	791	-	4.10-466.9	-	Marmara Sea
Yankova *et al.* (2009)				1.36:1	Black Sea
Šantić *et al.* (2011)	1411	9.2-37.9	7.9-466.0	1.10:1	Adriatic Sea
Atılgan *et al.* (2012)	439	7.7-31.0	3.97-47.46	-	Black Sea
Pešić *et al.* (2012)	730	8.9-31.3	-	1.59:1	Adriatic Sea
Kasapoğlu & Düzgüneş (2013)	624	6.2-19.5	1.71-64.30	-	Black Sea
Demirel & Yüksek (2013)	1224	13.5-19.4	-	1.22:1	Marmara-Black Sea
This study	754	11.5-34.9	22.29- 300.5	1.33:1	Northern Aegean Sea

for specimens measuring 13.5–19.4 cm in total length. In a separate study, Karlou-Riga (1995) reported batch fecundity values between 17,977 and 155,747 eggs for fish with ovary-free weights ranging from 93 to 366 g. The relatively higher fecundity values observed in the present study may be attributed to the broader size range of sampled individuals and the estimation of total fecundity rather than batch fecundity. Variation in fecundity among populations may be influenced by environmental factors such as temperature, sunlight, and weather conditions, with temperature likely representing the primary selective driver (Jonsson & Jonsson, 1999; Bithy *et al.,* 2012).

Regression analyses showed that the relationship between total fecundity and total weight was best described by a linear model, while a power function model was the best fit for the relationship between total fecundity and total length (Fig. 7). The fecundity–weight relationship exhibited a higher coefficient of determination ($R^2 = 0.9796$) compared to the fecundity–length relationship ($R^2 = 0.9255$), indicating a stronger association between fecundity and body mass. These findings are consistent with the biological principle that reproductive potential is more closely related to somatic energy reserves than to linear size. This pattern has also been observed in other teleost species. For instance, Fasya (2022) reported that in Betta species, the relationship between fecundity and total weight ($R^2 = 0.9319$) was significantly stronger than the relationship with total length ($R^2 = 0.1664$). Overall, these findings support the idea that body weight is as a more reliable predictor of fecundity, likely because it better reflects the energetic resources available for oocyte production.

CONCLUSIONS

This study provides the first comprehensive data on the reproductive biology of Trachurus mediterraneus in Edremit Bay, revealing key biological parameters for population assessment and management. The markedly female-biased sex ratio, early onset of sexual maturity at 18.6 cm TL, and extended spawning period from March to August—with a peak in April—highlight the species' reproductive capacity and ecological adaptation

Tab. 2: Reported L_{50} values for *Trachurus mediterraneus* **from various localities in the present and previous studies.**
Tab. 2: Poročane vrednosti L_{50} za vrsto *Trachurus mediterraneus* **z različnih lokalitet v pričujoči in predhodnih raziskavah.**

Reference	**Locality**	**L_{50} (cm)**
Fischer *et al*. (1987)	Mediterranean Sea	23
Karlou-Riga (1995)	Saronikos Gulf	20
Viette *et al*. (1997)	Adriatic Sea	16
Ragonose *et al*. (2002)	Central Mediterranean Sea	17.1-22.5
Samia *et al*. (2002)	Tunisian	15.7
Demirel & Yüksek (2013)	Marmara-Black Sea	12.2-12.5
Rodríguez-Castañeda *et al*. (2022)	Spanish Mediterranean	13.8-17.7
This study	Northern Aegean Sea	18.6

Tab. 3: Spawning seasons (by months) of *Trachurus mediterraneus* **at various localities in the present and previous studies.**
Tab. 3: Obdobja drstenja (po mesecih) za vrsto *Trachurus mediterraneus* **na različnih lokalitetah v pričujoči in predhodnih raziskavah.**

Reference	**Locality**	**Months**											
		J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Slastenenko (1956)	Marmara Sea				■	■	■	■	■				
Demir (1961)	Black Sea					■	■	■	■				
Fischer *et al*. (1987)	Mediterranean Sea						■	■	■				
Karlou-Riga (1995)	Saronikos Gulf				■	■	■	■	■	■			
Ünlüata *et al*. (1996)	Black Sea					■	■	■	■				
Viette *et al*. (1997)	Adriatic Sea					■	■	■	■	■	■		
Nannini *et al*. (1997)	Tyrrhenian Sea				■	■	■	■	■	■	■		
Karlou-Riga (2000)	Aegean Sea				■	■	■	■	■	■			
Ragonose *et al*. (2002)	Mediterranean Sea						■	■	■				
Samia *et al*. (2002)	Tunisian						■	■	■	■	■		
Šantić *et al*. (2006)	Adriatic Sea					■	■	■	■				
Şahin *et al*. (2009)	Black Sea							■	■	■			
Demirel & Yüksek (2013)	Marmara-Black Sea					■	■	■	■	■			
Melendez *et al*. (2017)	Alboran Sea					■	■	■	■				
Rodríguez-Castañeda *et al*. (2022)	Spanish Mediterranean					■	■	■	■				
This study	Northern Aegean Sea			■	■	■	■	■	■				

in the region. The inverse relationship between the gonadosomatic index and condition factor further confirms a distinctly seasonal reproductive cycle. Additionally, the strong correlations between batch fecundity and both total length and total weight indicate that body size is a reliable predictor of reproductive output.

These findings provide essential baseline information that can contribute to improved stock assessment models and the development of sustainable fisheries management strategies. Future research should aim to expand sampling across seasons and geographic regions to refine knowledge of reproductive traits and support more precise fisheries management.

RAZMNOŽEVALNA BIOLOGIJA SREDOZEMSKEGA ŠURA (*TRACHURUS MEDITERRANEUS*) V SKLOPU POPULACIJSKE RAZISKAVE V EDREMITSKEM ZALIVU (SEVERNO EGEJSKO MORJE)

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POZVETEK

*Pričujoča raziskava prinaša vpogled v razmnoževalne značilnosti sredozemskega šura (*Trachurus mediterraneus*) na podlagi analize 754 osebkov, zbranih v Edremitskem zalivu med septembrom 2008 in avgustom 2009. Skupno razmerje med spoloma je odstopalo od pričakovanega razmerja 1:1. Samice so spolno dozorele (L_{50}), ko so dosegle 18,6 cm v dolžino. Pregled gonad in analize gonadosomatskega indeksa so pokazali, da je drstenje potekalo od marca do avgusta, z viškom v aprilu. Fultonov kondicijski faktor je bil obratno sorazmeren gonadosomatskemu indeksu med obdobjem raziskave. Plodnost je bila med 2.738 in 48.315 oocitami in je kazala izrazito pozitivno korelacijo s totalno dolžino in celokupno maso. Te ugotovitve prinašajo ključne informacije o razmnoževalni biologiji te gospodarsko pomembne vrste in lahko prispevajo k trajnostnemu upravljanju njenih populacij v Egejskem morju.*

Ključne besede: *Trachurus mediterraneus*, drstenje, plodnost, Edremitski zalivu

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PHYSALIA PHYSALIS IN THE CENTRAL MEDITERRANEAN SEA: RECENT OBSERVATIONS IN RELATION TO MASS STRANDINGS OF *VELELLA VELELLA* AND SURFACE CIRCULATION DYNAMICS

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ABSTRACT

The Portuguese man-of-war, Physalia physalis *(Linnaeus, 1758), is a pleustonic siphonophore distributed throughout tropical and subtropical oceans. Although the species is occasionally recorded in the Mediterranean Sea, its occurrence is generally linked to episodic advection driven by winds and surface currents. Here, we report observations of* P. physalis *in the central Mediterranean between 6 February and 6 March 2026, coinciding with massive strandings of the pleustonic hydrozoan* Velella velella. *A negative North Atlantic Oscillation (NAO) phase likely facilitated Atlantic water inflow and eastward transport into the Mediterranean. A drifter trajectory from the southern Tyrrhenian Sea indicated temporary retention near the Lipari coast. These records likely indicate a transient influx of* P. physalis*, rather than a stable Mediterranean population.*

Key words: Portuguese man-of-war, pleuston, jellyfish strandings, wind-driven circulation, multiplatform approach, teleconnection pattern

PHYSALIA PHYSALIS NEL MAR MEDITERRANEO CENTRALE: RECENTI OSSERVAZIONI ASSOCIATE A SPIAGGIAMENTI MASSIVI DI *VELELLA VELELLA* E ALLE DINAMICHE DELLA CIRCOLAZIONE SUPERFICIALE

SINTESI

La caravella portoghese, Physalia physalis *(Linnaeus, 1758), è un sifonoforo pleustonico degli oceani tropicali e subtropicali, occasionalmente segnalato nel Mediterraneo in seguito a eventi episodici di avvezione da venti e correnti superficiali. In questo lavoro riportiamo osservazioni nel Mediterraneo centrale tra il 6 febbraio e il 6 marzo 2026, associate a spiaggiamenti massivi dell'idrozoo pleustonico* Velella velella. *L'evento è stato probabilmente favorito da una fase negativa della North Atlantic Oscillation (NAO), che ha promosso l'ingresso di acque superficiali atlantiche e il trasporto verso est, come supportato dalla traiettoria di un drifter nel Tirreno meridionale con temporanea ritenzione presso la costa di Lipari. Queste segnalazioni riflettono verosimilmente un evento transitorio di avvezione piuttosto che l'instaurarsi di una popolazione stabile nel Mediterraneo.*

Parole chiave: caravella portoghese, pleuston, spiaggiamenti di meduse, circolazione guidata dal vento, approccio multipiattaforma, teleconnection patterns

INTRODUCTION

The Mediterranean Sea is recognized as one of the world's major marine biodiversity hotspots, hosting an exceptionally rich fauna with more than 17,000 recorded marine species (Coll *et al.*, 2010; Kokkinos *et al.*, 2025). Despite this remarkable diversity, Mediterranean ecosystems are undergoing rapid ecological change driven by multiple anthropogenic and climatic factors, including biological invasions, expansion of neonative species, ocean warming, and alterations in circulation patterns (Katsanevakis *et al.*, 2014; Giangrande *et al.*, 2020; Tiralongo *et al.*, 2020; Darmaraki *et al.*, 2024; Martellucci *et al.*, 2025).

Among gelatinous zooplankton, pleustonic organisms living at the sea surface represent a peculiar ecological component of pelagic ecosystems. These species, which include hydrozoans such as *Physalia physalis* (Linnaeus, 1758) and *Velella velella* (Linnaeus, 1758), depend largely on wind-driven transport and surface currents for their dispersal and distribution (Iosilevskii & Weihs, 2009; Lee *et al.*, 2021; Carvalho *et al.*, 2026). Consequently, their occurrence in coastal areas is often episodic and strongly influenced by meteorological conditions, which can lead to large-scale accumulations and strandings along shorelines (Prieto *et al.*, 2015; Macías *et al.*, 2021).

The Portuguese man-of-war, *P. physalis*, is a cosmopolitan siphonophore distributed in tropical and subtropical waters, characterized by a gas-filled float (pneumatophore) that enables it to drift at the sea surface while trailing long tentacles armed with powerful nematocysts (Mapstone, 2014; Munro *et al.*, 2019). Although often mistaken for a true jellyfish (Scyphozoa), the Portuguese man-of-war is a highly specialized colonial organism (Hydrozoa), composed of multiple functionally differentiated zooids. Due to the highly potent venom contained in the nematocysts, contact with the tentacles can cause severe, painful stings and dermatological reactions in humans. As a result, the nearshore occurrence of *P. physalis* colonies represents a potential hazard for swimmers and coastal recreational activities (Toubarro *et al.*, 2023).

In the Mediterranean Sea, *P. physalis* is generally regarded as an occasional visitor rather than a resident species. Its occurrence is usually associated with episodic advection events involving Atlantic

Fig. 1: (A) Colony of** Physalia physalis **among numerous individuals of** Velella velella **observed at Ustica Island on 24 February 2026; (B) The colony of** P. physalis **was subsequently collected and preserved by Tatiana Geloso (author of the photos).

Sl. 1: (A) Kolonija vrste** Physalia physalis **med številnimi osebki vrste** Velella velella**, opažena na otoku Ustica 24. februarja 2026; (B) Kolonijo** P. physalis **je pozneje prevzela in konzervirala Tatiana Geloso (avtorica fotografij).

populations entering through the Strait of Gibraltar, with frequent strandings reported along the Spanish and North African coasts of the Alboran Sea (Tiralongo *et al*., 2022). A key driver of this inflow is the negative phase of the North Atlantic Oscillation (NAO), which favors westerly wind conditions that enhance the entry of Atlantic surface waters into the Mediterranean (Prieto *et al*., 2015; Macías *et al*., 2025). More generally, recent studies have highlighted the importance of basin-scale surface circulation and wind-driven transport in shaping the dispersal and coastal occurrence of this pleustonic species within the western Mediterranean (Macías *et al*., 2021; Macías *et al*., 2025). In addition, the complex surface circulation of the Alboran Sea, including cyclonic and anticyclonic structures and the Almeria–Oran front (Tintore *et al*., 1988; Macías *et al*., 2016; Capó *et al*., 2021; Martellucci *et al*., 2025), may increase the residence time of floating organisms in the area, thereby favoring coastal accumulation and stranding (Prieto *et al*., 2015). For this reason, records from across the Mediterranean remain relatively rare and are often linked to short-lived stranding events (Tiralongo *et al*., 2022; Macías *et al*., 2025).

A pleustonic hydrozoan frequently involved in mass stranding events in the Mediterranean is *V. velella*, commonly known as the "by-the-wind sailor". This species forms large pelagic aggregations that may be transported toward the coast by persistent winds, resulting in spectacular accumulations along beaches. Such events are relatively common in the Mediterranean basin and may involve millions of individuals. Because both *P. physalis* and *V. velella* inhabit the sea–air interface and rely heavily on wind-driven transport, their occurrences are often linked to the same oceanographic and meteorological conditions. Consequently, episodes of massive *Velella* strandings may occasionally coincide with the presence of other pleustonic organisms drifting in the same surface water masses.

In this study, we report a series of recent observations of *P. physalis* consistently associated with massive strandings of the pleustonic hydrozoan *V. velella* along the Italian and Maltese coasts, mainly localized between Sicily and Calabria during a short period in winter 2026. Using a multiplatform approach that integrates citizen science with atmospheric and oceanographic data, we investigate the mechanisms underlying these pleustonic transport events from Gibraltar Straits toward the central Mediterranean coasts.

MATERIAL AND METHODS

Between 6 February and 6 March 2026, several colonies of *Physalia physalis* were observed and photographed by coastal observers along coastal sectors of southern Italy, between Sardinia, Sicily, and Calabria (central Mediterranean Sea).

The first observation occurred on 24 February 2026 on Ustica Island (38.70551 °N, 13.15842 °E), when several colonies were photographed near the shoreline during a period characterized by extensive beach accumulations of *Velella velella* (Fig. 1). A second observation was recorded on 27 February 2026 in Villa San Giovanni (38.23886 °N, 15.66730 °E), again in association with massive strandings of *V. velella*. A later observation was documented on 3 March 2026 in

Tab. 1. Documented observations of *Physalia physalis* ***colonies recorded between 6 February and 6 March 2026, including the main details and sources of each record. A single colony was observed per location and date.***
Tab. 1. Dokumentirana opažanja kolonij vrste *Physalia physalis****, zabeležena med 6. februarjem in 6. marcem 2026, vključujejo glavne podrobnosti in vire za vsak zapis o pojavljanju, pri čemer je bila na posamezno lokacijo in datum opažena po ena sama kolonija.***

Date	Location	Country	Coordinates	Source
6 February 2026	Granitola Torretta	Italy	37.57269° N, 12.65768° E	iNaturalist
14 February 2026	Buggerru	Italy	39.42762° N, 8.41308° E	iNaturalist
20 February 2026	Lamezia Terme	Italy	38.91625° N, 16.21929° E	online magazine
24 February 2026	Ustica	Italy	38.70551° N, 13.15842° E	observer
27 February 2026	Villa San Giovanni	Italy	38.23886° N, 15.66730° E	observer
1 March 2026	Lipari	Italy	38.49229° N, 14.88063° E	Facebook
3 March 2026	Pizzo Calabro	Italy	38.79915° N, 16.20872° E	observer
6 March 2026	Sliema	Malta	35.91798° E, 14.49985° E	iNaturalist

Pizzo Calabro (38.79915 °N, 16.20872 °E), confirming the persistence of the event over several consecutive days. Moreover, during the same period, additional observations were publicly reported by local online news outlets. For instance, a record dated 20 February 2026 from Lamezia Terme (Tyrrhenian Sea - 38.91625 °N, 16.21929 °E) was reported by *Corriere della Calabria* (2026). In this case as well, colonies of *P. physalis* were observed in association with a massive stranding of *V. velella* on the shoreline, forming dense beach wrack lines. Another observation was reported on 1 March 2026 from Lipari, Aeolian Islands (Tyrrhenian Sea – 38.49229 °N, 14.88063 °E) and documented through photographic evidence shared on Facebook (2026). Additional observations from the same period were retrieved from the online platform iNaturalist (2026) (Fig. 2, Tab. 1). Species identification relied on the characteristic morphology of *P. physalis*, including a bluish-violet gas-filled float and long trailing tentacles, which were clearly visible in the examined photographs.

To investigate the causes of these events along the Tyrrhenian coasts of southern Italy, and given the pleustonic nature of the species, we adopted a multi-platform approach to identify the main forcing factors that may have favored its arrival in the Tyrrhenian Sea. We examined atmospheric and oceanographic conditions using a combination of large-scale climatic indices, regional oceanic and atmospheric models, and in situ observations from various data portals.

Surface circulation fields were obtained using the Copernicus Marine Service Mediterranean Sea Physics Analysis/Forecast product MEDSEA_MULTIYEAR_PHY_006_004 (DOI: 10.25423/CMCC/MEDSEA_MULTIYEAR_PHY_006_004_E3R1), which is based on the Mediterranean Forecasting System and provided on a regular 1/24° horizontal grid (approximately 4–5 km resolution). For our analysis, we used the hourly two-dimensional sea-surface current fields, specifically the eastward and northward velocity components (uo, vo, m s^{-1}). Surface current anomalies were computed by subtracting the monthly climatological mean from the January–February 2026 fields, then averaged over the same period. The zonal component is shown in Fig. 2.

Wind data were retrieved from the ERA5 hourly dataset at individual atmospheric levels, provided by the Copernicus Climate Change Service (DOI: 10.24381/cds.adbb2d47). To characterize the large-scale atmospheric forcing over the northeastern Atlantic, the monthly mean zonal wind component was averaged over the 30–50° N and 20–10° W domain for September 2025–February 2026. This quantified the seasonal evolution of westerly winds affecting the Atlantic sector adjacent to the southwestern Iberian margin.

The North Atlantic Oscillation (NAO) index values were obtained from the NOAA Climate Prediction Center (CPC) teleconnection archive and used as a large-scale climatic indicator for atmospheric circulation patterns over the North Atlantic–Mediterranean region.

Wave conditions in the central Mediterranean were analyzed using data from the Italian National Wave Network (www.mareografico.it), based on observations from the Palermo wave buoy. Significant wave height and wave direction were examined to describe the dominant wave regime and identify energetic wave events occurring in the weeks preceding the coastal observations.

Direct current observations were provided by the SVP (Surface Velocity Program) drifters drogued at 15 m (Niiler, 2001; Centurioni, 2018). SVP drifters follow sub-surface currents within 1 cm s^{-1} in winds up to 10 m s^{-1} (Niiler *et al.*, 1995). Drifter positions were quality-controlled using standard methods (Menna *et al.*, 2017). Water mass acronyms used in this paper follow Schroeder *et al.* (2024).

Since the dataset consisted of only eight opportunistic presence-only records concentrated within a short temporal window, the observations were not treated as independent statistical replicates. Therefore, no formal correlation analysis was performed between *P. physalis* sightings and environmental variables. Instead, the environmental analysis was conducted at the event scale, using wind fields, surface current anomalies, wave conditions, and drifter trajectories to assess whether the physical conditions were consistent with episodic eastward advection and subsequent coastal accumulation.

RESULTS AND DISCUSSION

The colonies observed during the investigation period displayed the typical morphological features of *Physalia physalis*, including an elongated bluish pneumatophore and trailing tentacles extending beneath the float (Fig. 1). Although the number of individuals observed was relatively limited (Fig. 2a, Tab. 1), their repeated occurrence within a short temporal window suggests the passage and/or coastal accumulation of a surface-drifting pleustonic aggregation advected along the Atlantic Water surface pathway, with wind drift and wave forcing likely modulating its final coastal displacement.

All observations occurred simultaneously with massive strandings of *Velella velella*, which formed extensive accumulations along beaches. Such events are relatively common in the Mediterranean and are generally associated with persistent winds that push surface-drifting organisms toward coastal sectors (Betti *et al.*, 2019). The co-occurrence of *P. physalis* and *V. velella* strongly suggests that

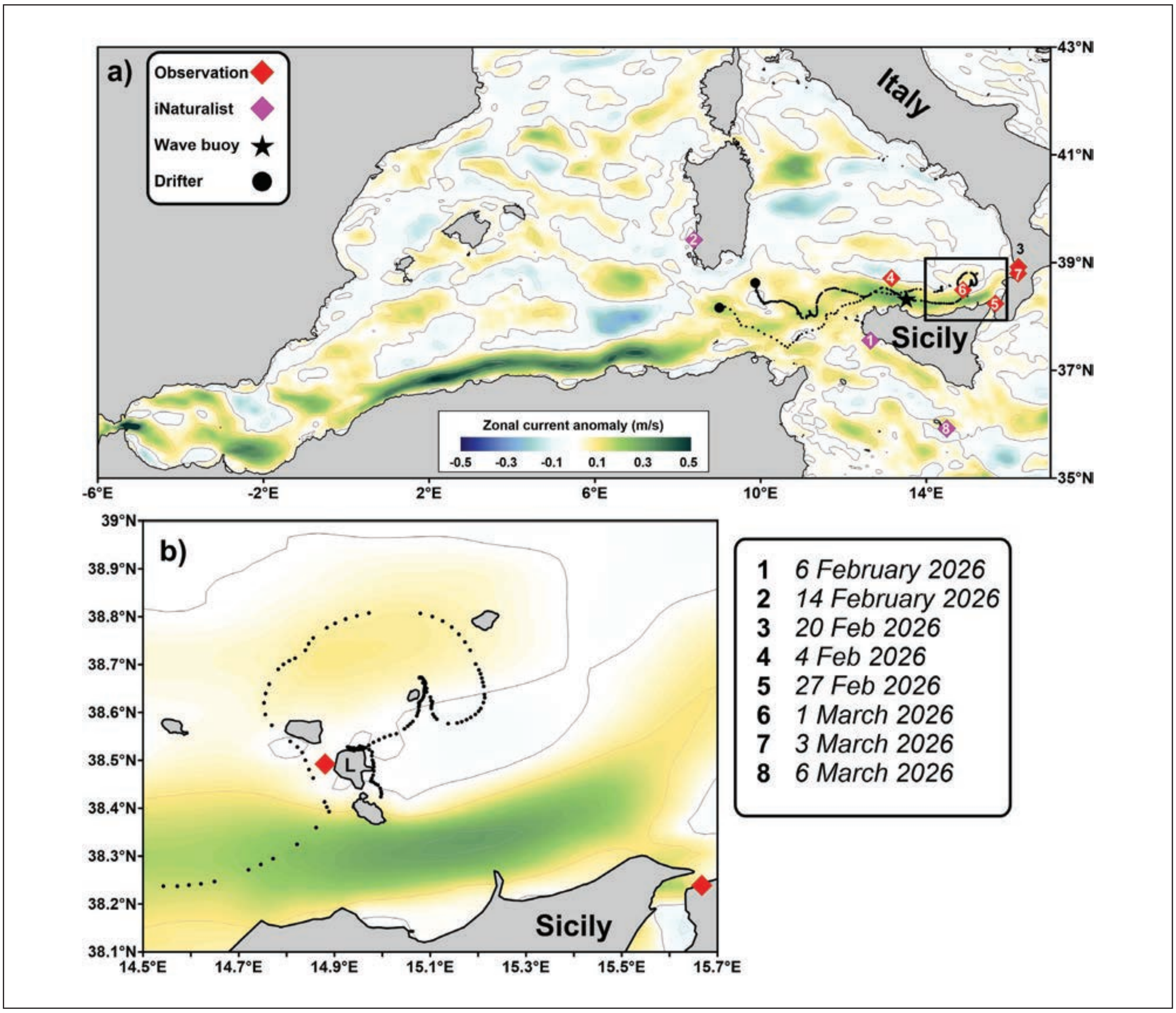

Fig. 2: (a) Map of the anomaly of the zonal component of the current field for January and February 2026; zoom on the Lipari island. (b) Diamonds indicate* Physalia *observations, the star marks the location of the wave buoy of the National Tide Gauge Network. Black dots represent the trajectory of the SVP drifter from 10 February 2026 to 10 March 2026 (IMEI: a300534065360410; a300534065378310).

Sl. 2: (a) Zemljevid anomalije zonalne komponente tokovnega polja za januar in februar 2026; povečava (zoom) na otok Lipari. (b) Diamanti označujejo opažanja vrste* Physalia*, zvezdica označuje lokacijo valomernega plovka nacionalne mreže mareografskih postaj. Črne pike predstavljajo tirnico SVP oceanskega plovka (drifterja) od 10. februarja 2026 do 10. marca 2026 (IMEI: a300534065360410; a300534065378310).

both species were transported by the same surface currents and wind systems. As pleustonic organisms are largely passive drifters, their distribution is highly dependent on meteorological forcing, particularly wind direction and intensity (Headlam *et al.*, 2020). Under favorable conditions, offshore aggregations may therefore be transported toward coastal areas over relatively short time scales. In this context, mass strandings of *V. velella* may serve as a useful biological proxy for the arrival of larger oceanic pleustonic organisms, including *P. physalis*, particularly during periods of persistent onshore winds, enhanced surface circulation, and storm-related transport events. Similar associations between meteorological forcing, pleuston accumulation, and coastal strandings have been documented in previous studies on *V. velella* and other neustonic organisms (Karunarathne & de Croos, 2022; Roca *et al.*, 2025). Given the limited number of observations and their temporal clustering, the sightings were interpreted as manifestations of a single advection event rather than as independent records suitable for point-by-point statistical correlation. Accordingly, the environmental analysis was performed at the event scale.

The atmospheric–oceanographic context preceding February–March 2026 provides a coherent framework for interpreting these events. The cold season of 2025–2026 was characterized by a predominantly negative NAO phase (Fig. 3). During the same period, the monthly mean zonal wind component over the northeastern Atlantic sector (30–50° N, 20–10°W) remained persistently positive, increasing progressively from autumn to winter and reaching maximum values in January–February 2026. This pattern indicates strengthened westerly winds over the Atlantic sector adjacent to the southwestern Iberian margin, favoring the entry of pleustonic organisms into the Mediterranean Sea. Such conditions have previously been associated with the eastward displacement of *P. physalis* toward the southwestern Iberian margin and the western Mediterranean (Prieto *et al.*, 2015), and are consistent with the basin-scale transport framework proposed by Macías *et al.* (2021) as well as with more recent observations reported by Macías *et al.* (2025). This interpretation is also coherent with the well-known wind-driven drift of this pleustonic organism (Iosilevskii & Weihs, 2009; Lee *et al.*, 2021). The intensification of westerlies during autumn–winter 2025–2026 has favored the initial transport of offshore colonies from the northeastern Atlantic toward the entrance to the Mediterranean Basin.

Surface circulation in the Mediterranean Sea is primarily driven by the inflow of Atlantic Water (AW) through the Strait of Gibraltar (Poulain *et al.*, 2013). After entering the basin, AW spreads eastward across the western Mediterranean, generating meanders, mesoscale eddies, and dynamical instabilities along its trajectory (Bergamasco & Malanotte-Rizzoli, 2010). The current then follows the North African margin up to Sicily, where the flow bifurcates (Millot & Taupier-Letage, 2005; Iacono *et al.*, 2013). One main branch continues eastward toward the eastern Mediterranean, while the other turns northward and enters the Tyrrhenian Sea. Within the Tyrrhenian basin, this surface circulation pathway flows northwestward along the Italian coastline (Martellucci *et al.*, 2018), transporting

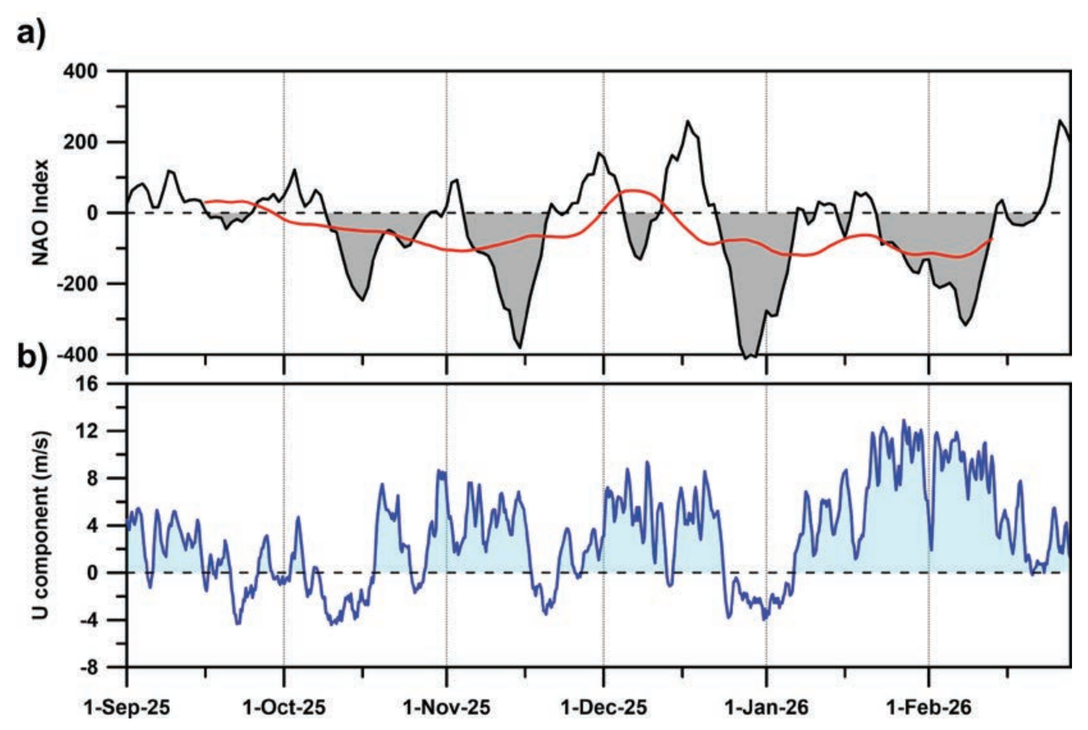

Fig. 3. (a) NAO index (black line) and its 13-month running mean; the grey shaded area highlights periods with negative values; (b) zonal wind component averaged over the region 30–50° N, 20–10° W (blue line); the cyan shaded area indicates positive values, corresponding to eastward-blowing winds.
Sl. 3. (a) Indeks NAO (črna črta) in njegova 13-mesečna drseča sredina; sivo osenčeno območje poudarja obdobja z negativnimi vrednostmi; (b) zonalna komponenta vetra, povprečena čez regijo 30–50° S, 20–10° Z (modra črta); sinje modro osenčeno območje označuje pozitivne vrednosti, ki ustrezajo vetrovom, ki pihajo proti vzhodu.

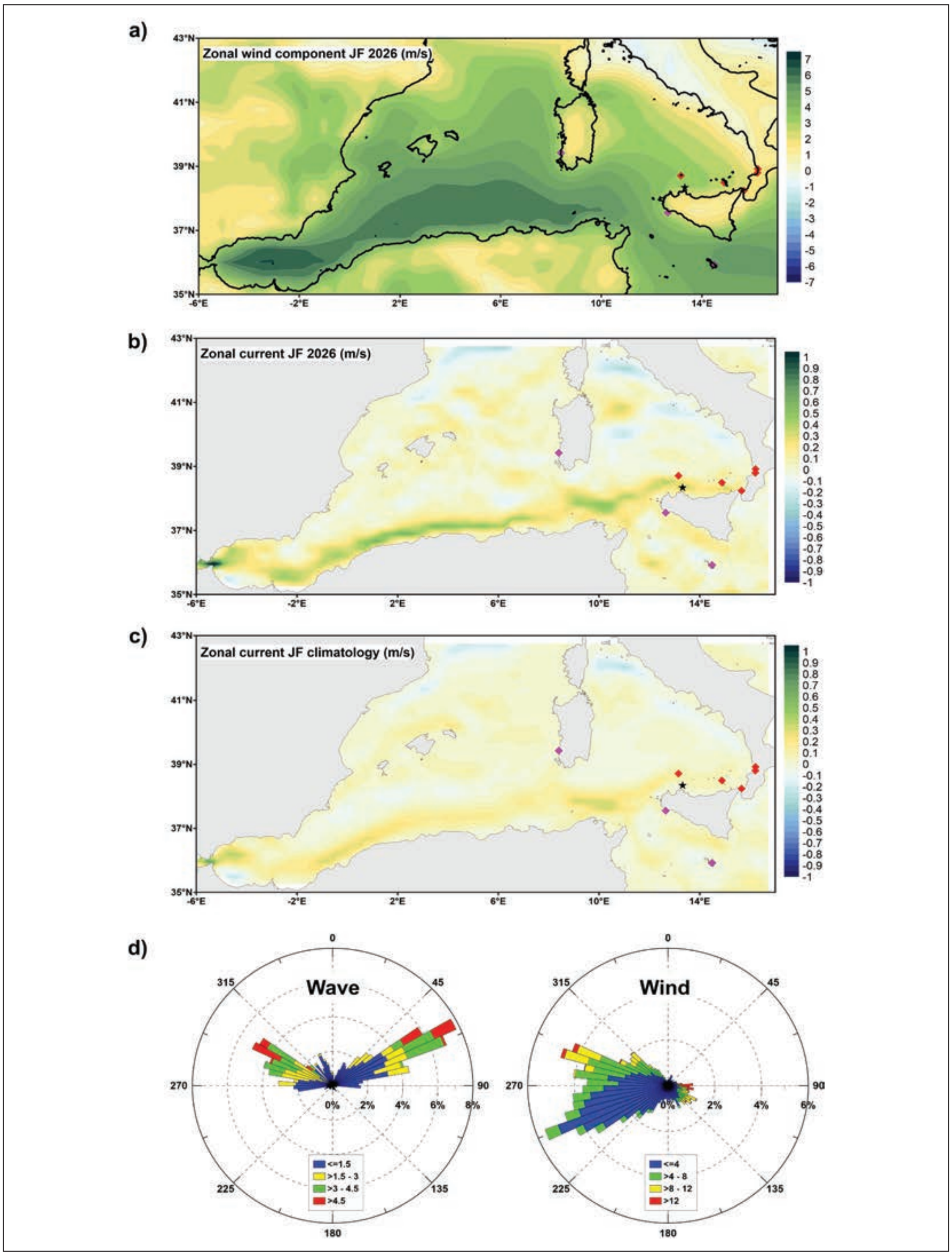

Fig. 4. (a) Zonal component of the wind, (b) current, and (c) current climatology, averaged over January and February 2026; diamonds indicate* P. physalis *observations, the star marks the location of the wave buoy of the National Tide Gauge Network; (d) Wind rose for the Palermo tide gauge station, showing wind and wave data. Note: current direction indicates water movement, wind direction indicates the origin of the wind.

Sl. 4. (a) Zonalna komponenta vetra, (b) morski tok in (c) klimatologija morskih tokov, povprečeni čez januar in februar 2026; diamanti označujejo opažanja vrste* P. physalis*, zvezdica označuje lokacijo valomernega plovka nacionalne mreže mareografskih postaj; (d) vetrna rožа za mareografsko postajo Palermo, ki prikazuje podatke o vetru in valovih. Opomba: smer toka označuje gibanje vode, smer vetra pa označuje izvor (od kod piha) vetra.

water masses toward the northwestern sector of the basin (Millot & Taupier-Letage, 2005; Iacono *et al.*, 2013). Accordingly, the observations reported here are consistent with the hypothesis that *P. physalis* can be advected within the Mediterranean by the main AW surface pathways after entering from the Atlantic, as previously suggested by basin-scale modelling studies (Macías *et al.*, 2021).

Once within the Mediterranean, oceanographic conditions during January–February 2026 appear to have favored further eastward propagation. The anomaly of the zonal component of the surface current relative to climatology (Fig. 2a) revealed positive values across several key sectors, including the North African margin, the Sardinia and Sicily Channels, and the southern Tyrrhenian Sea. This pattern suggests enhanced eastward surface transport relative to the climatological mean (>60%, Fig. 4b,c), broadly following the main Atlantic Water circulation pathway in the western and central Mediterranean (Poulain *et al.*, 2012; Menna *et al.*, 2022). At the same time, the mean zonal wind field over the western and central Mediterranean basin remained predominantly positive, indicating widespread eastward atmospheric forcing that may have reinforced the surface current system (Fig. 4a).

Importantly, the drifter trajectory recorded between 10 February and 10 March provides independent Lagrangian evidence for the hypothesized surface transport pathway of the Portuguese man-of-war (Fig. 2a). Unlike a point-by-point correlation between a limited number of sightings and environmental variables, the drifter trajectory directly documents the displacement of a surface-following object under the combined action of currents and wind forcing.

A particularly relevant feature is that the drifter (IMEI: a300534065360410) was already located very close to the Lipari coast on 1 March, coinciding with the location and timing of one of the recorded sightings, and remained in the area until 6 March, describing small looping trajectories. This provides further Lagrangian support for the hypothesis on local accumulation and temporary retention of pleustonic organisms near the coast (Fig. 2b).

In situ wave and wind conditions in the southern Tyrrhenian Sea (Fig. 4d) further support this interpretation. Data from the Palermo wave buoy (Fig. 4d) show that the weeks preceding the coastal observations were characterized by a persistent W–NW/NW wave regime, with peak events exceeding 5 m. Notably, the observations recorded in the Sicily Channel – the first and the last reported here – suggest that the spreading of *P. physalis* was not confined to the western Mediterranean, but extended into the central basin (Fig. 2a). This agrees with previous modelling results indicating that, after entering through the Strait of Gibraltar, *P. physalis* can be advected toward the Sicily Channel (Macías *et al.*, 2021).

Given the pleustonic nature of *P. physalis*, the persistent W–NW/NW wind and wave regime likely played a key role in the final coastal approach and accumulation of colonies along the northern Sicilian margin. More generally, the event is best interpreted as a combined wind–current–wave surface-drift process. At the basin scale, the Atlantic Water circulation and anomalous eastward surface-current patterns observed in January–February 2026 provided a favorable advective framework toward the central Mediterranean and Tyrrhenian sectors. At smaller spatial and temporal scales, persistent westerly winds, energetic wave conditions, windage, and mesoscale circulation features likely modulated the drift, retention, and coastal accumulation of pleustonic colonies. This interpretation is consistent with Prieto *et al.* (2015), who linked Mediterranean occurrences of *P. physalis* to unusual combinations of meteorological and oceanographic conditions, and with Macías *et al.* (2021), who proposed a Lagrangian transport framework for its dispersal within the Mediterranean.

Although *P. physalis* is occasionally reported from the Mediterranean Sea, its occurrences remain sporadic and are generally linked to episodic incursions of Atlantic surface waters (Prieto *et al.*, 2015; Tiralongo *et al.*, 2022; Macías *et al.*, 2025). The observations reported here are therefore most likely a reflection of a transient advection-driven occurrence, rather than of the establishment of a self-sustaining or stable population within the basin. Similar episodic transport events have been documented in the western Mediterranean and are typically associated with specific combinations of atmospheric forcing and regional circulation patterns (Prieto *et al.*, 2015; Macías *et al.*, 2021; Macías *et al.*, 2025).

From an ecological perspective, such events provide valuable insights into surface circulation dynamics and the transport of neustonic communities across the Mediterranean basin. The simultaneous occurrence of different pleustonic taxa, such as *P. physalis* and *V. velella*, may reflect large-scale aggregation processes occurring offshore before wind-driven transport toward coastal areas.

When interpreted together with current anomalies, wind fields, wave conditions, and the drifter trajectory, these episodic strandings may provide qualitative evidence of transient surface-drift routes connecting Atlantic-influenced waters with the central Mediterranean. However, for pleustonic organisms, such transport should not be attributed to currents alone, as wind drift and wave forcing likely play a major role, particularly during the final coastal accumulation phase. In this context, surface drifters represent a particularly valuable tool for interpreting such episodic events, as the Lagrangian observations they provide represent direct evidence of transport and retention processes that cannot be robustly inferred from sparse presence-only records alone.

Furthermore, the increasing availability of photographic documentation from coastal observers and citizen science networks greatly enhances our ability to detect and document such transient events (Carvalho *et al*., 2026). Rapid reporting of unusual occurrences contributes to improving our understanding of the dynamics of gelatinous plankton and pleustonic communities in the Mediterranean Sea. Given the episodic nature of these phenomena, continued monitoring of Mediterranean coastlines will be essential to better understand the frequency, drivers, and ecological implications of incursions of Atlantic pleustonic organisms such as *P. physalis* into the basin.

Future studies should complement observational records with dedicated Lagrangian modelling approaches, in which virtual particles representing pleustonic colonies are advected under different combinations of surface currents, windage, and wave-related forcing. Such an approach would allow testing of alternative transport scenarios and estimation of residence times, likely drift pathways, and potential stranding areas. In addition, considering the potentially dangerous stings of this species for humans, improved knowledge of when and where *P. physalis* occurs near the coast is highly valuable for public awareness and coastal management.

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PORTUGALSKA LADJICA (*PHYSALIA PHYSALIS*) V OSREDNJEM SREDOZEMSKEM MORJU: NEDAVNA OPAŽANJA V POVEZAVI Z MASOVNIMI NASEDANJI MORSKEGA JADRČKA (*VELELLA VELELLA*) IN DINAMIKO POVRŠINSKEGA KROŽENJA VODE

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POVZETEK

Portugalska ladjica, Physalia physalis *(Linnaeus, 1758), spada med plevstonske vrste cevkašev in je razširjena po vseh tropskih in subtropskih oceanih. Čeprav vrsto v Sredozemskem morju zabeležijo le občasno, je njeno pojavljanje splošno povezano z epizodično advekcijo, ki jo poganjajo vetrovi in površinski tokovi. Avtorji poročajo o opažanjih vrste* P. physalis *v osrednjem Sredozemlju med 6. februarjem in 6. marcem 2026, kar sovpada z masovnimi nasedanji vrste plevstonskega trdoživnjaka* Velella velella*. Negativna faza severnoatlantske oscilacije (NAO) je verjetno olajšala dotok atlantske vode in njen transport proti vzhodu v Sredozemlje. Tirnica oceanskega plovka (drifterja) iz južnega Tirenskega morja je pokazala začasno zadrževanje v bližini obale otoka Lipari. Ta opažanja verjetno kažejo na prehoden pojav vrste* P. physalis *in ne na stabilno populacijo v Sredozemskem morju.*

Ključne besede: portugalska ladjica, plevston, nasedanje meduz, vetrno gnano kroženje vode, večplatformni pristop, vzorec telekonekcije

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FIRST CONTRIBUTION TO THE STUDY OF THE "SEA SLUG" FAUNA (GASTROPODA, HETEROBRANCHIA) OF THE ALGERIAN COAST

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ABSTRACT

In Algeria, studies concerning the informally defined group of "sea slugs" have so far focused exclusively on sporadic records of species from various areas of the local coast. Consequently, the sea slug fauna of the Algerian coast remains largely unknown. This study aimed to compile the first list of sea slugs in the Algerian coast by examining new photographic and field data collected between 2010 and 2025. Based on these new data and published literature, it has been possible to confirm that 71 species belonging to 35 families of sea slugs have been recorded in the region to date. Given the historical lack of experts on this faunal group in Algeria and the high marine environmental diversity of its coast, this number is likely a great underestimation.

Key words: Algeria, inventory, citizen science, heterobranch sea slugs, marine heterobranchs, opisthobranchs

PRIMO CONTRIBUTO ALLO STUDIO DELLA FAUNA A "LUMACHE DI MARE" (GASTROPODA, HETEROBRANCHIA) DELLA COSTA ALGERINA

SINTESI

In Algeria, gli studi riguardanti il gruppo definito in modo informale "lumache di mare" si sono finora concentrati esclusivamente su segnalazioni sporadiche di specie provenienti da diverse aree della costa locale. Di conseguenza, la fauna a lumache di mare della costa algerina rimane in gran parte sconosciuta. Questo studio ha l'obiettivo di compilare la prima lista delle lumache di mare presenti lungo la costa algerina, esaminando nuovi dati fotografici e osservazioni sul campo raccolti tra il 2010 e il 2025. Sulla base di questi nuovi dati e della letteratura scientifica pubblicata, è stato possibile confermare che nella regione sono state finora segnalate 71 specie appartenenti a 35 famiglie. Considerata la storica mancanza di esperti di questo gruppo faunistico in Algeria e l'elevata diversità ambientale degli ecosistemi marini della sua costa, questo numero è probabilmente fortemente sottostimato.

Parole chiave: Algeria, inventario, scienza partecipativa, lumache di mare eterobranchie, eterobranchi marini, opistobranchi

INTRODUCTION

The Algerian coastline, extending over 2148 km along the southwestern Mediterranean basin (El Watan, 2023), is characterised by marked geomorphological heterogeneity that results in a wide variety of coastal marine environments (Millot, 1999). Specifically, rocky shores dominate large portions of the coast, while sandy beaches and dune systems are mainly developed within broad embayments (Grimes *et al.,* 2010). This structural heterogeneity, combined with strong longitudinal gradients in hydrodynamics, productivity, and substrate composition, creates the conditions suitable for a wide range of marine habitats (*e.g.,* soft-bottom assemblages, seagrass meadows of *Posidonia oceanica* (Linnaeus) Delile, and coralligenous formations), which collectively contribute to the high environmental diversity of the Algerian coastal area within the southwestern Mediterranean context (Grimes *et al.,* 2016).

Despite the remarkable richness of the Algerian marine environment, faunal research remains limited and has been predominantly focused on general surveys of the main groups of marine animals, such as fish, crustaceans, polychaetes, and molluscs. This situation is linked to numerous factors, including limited interest in purely faunistic studies, limited resources for studying marine faunas, and a shortage of taxonomists (Grimes *et al.,* 2004).

Historically, one of the groups of marine molluscs less frequently considered in Algerian studies is that of sea slugs. Comprising 13 higher-level taxa

Tab. 1: Algerian sea slug reports in the literature to date. For each species, locality(ies), reference(s) and chorotype are indicated. Chorotype abbreviations are as follows: ME = Mediterranean endemic; AM = Atlantic–Mediterranean; BA = Boreo-Atlantic; SA = subtropical Atlantic; IP = Indo-Pacific; PO = pan-oceanic; UD = Unknown distribution. The abbreviation NS stands for "Not specified".

Tab. 1: Poročila o alžirskih golih morskih polžih v razpoložljivi literaturi. Za vsako vrsto so navedeni lokaliteta(-e), vir(-i) in horotip. Kratice horotipov so naslednje: ME = sredozemski endemit; AM = atlantsko-sredozemski; BA = boreo-atlantski; SA = subtropski atlantski; IP = indo-pacifiški; PO = pan-oceanski; UD = neznana razširjenost. Kratica NS pomeni „ni določeno".

Taxon	Locality	Reference	Chorotype
Acteonoidea			
Family Acteonidae d'Orbigny, 1842			
Acteon tornatilis (Linnaeus, 1758)	Bay of Algiers; Bay of Fetzara	Bakalem, 2008	BA
Ringiculimorpha			
Family Ringiculidae Philippi, 1853			
Ringicula buccinea (Brocchi, 1814)	Bay of Fetzara	Bakalem, 2008	BA
Ringicula sp.	Bay of Fetzara	Bakalem, 2008	UD
Nudibranchia			
Family Facelinidae Bergh, 1889			
Cratena peregrina (Gmelin, 1791)	Annaba	Derbal & Kara, 2005	AM
Facelina auriculata (Müller, 1776)	Bay of Algiers	Bakalem, 2008	BA
Family Flabellinidae Bergh, 1889			
Flabellina affinis (Gmelin, 1791)	Annaba	Derbal & Kara, 2005	AM
	Réghaïa	CAR/ASP-PLUE/PAM, 2015	
Family Myrrhinidae Bergh, 1905			
Godiva quadricolor (Barnard, 1927)	Port of Arzew	Bensari *et al.*, 2020	PO
Nemesignis banyulensis (Portmann & Sandmeier, 1960)	Artificial reef of Oran	Tamsouri *et al.*, 2018	AM
Family Fionidae Gray, 1857			
Fiona pinnata (Eschscholtz, 1831)	Bay of Algiers	Bakalem, 2008	PO
Family Samlidae Korshunova, Martynov, Bakken *et al.*, 2017			
Luisella babai (Schmekel, 1972)	Réghaïa	CAR/ASP-PLUE/PAM, 2015	AM

Family Tethydidae Rafinesque, 1815			
Tethys fimbria Linnaeus, 1767	NS	Pruvot-Fol, 1954	AM
Doridida			
Family Chromodorididae Bergh, 1891			
Felimare tricolor (Cantraine, 1835)	Annaba	Derbal & Kara, 2005	AM
	Réghaïa	CAR/ASP-PLUE/PAM, 2015	
Rudmania purpurea (Risso, 1831)	Artificial reef of Oran	Tamsouri *et al.*, 2018	AM
Family Discodorididae Bergh, 1891			
Jorunna tomentosa (Cuvier, 1804)	Annaba	Camacho-García & Gosliner, 2008	BA
Peltodoris atromaculata Bergh, 1880	Annaba	Derbal & Kara, 2005	AM
	Réghaïa	CAR/ASP-PLUE/PAM, 2015	
Platydoris argo (Linnaeus, 1767)	NS	Pruvot-Fol, 1954	AM
Family Dorididae Rafinesque, 1815			
Doris verrucosa Linnaeus, 1758	Bay of Algiers	Bakalem, 2008	SA
Cephalaspidea			
Family Bullidae J. E. Gray, 1827			
Bulla striata Bruguière, 1792	NS	Pruvot-Fol, 1954	SA
Family Retusidae Thiele, 1925			
Retusa variabilis (Milaschewitsch, 1912)	Bay of Algiers	Bakalem, 2008	ME
Family Cylichnidae H. Adams & A. Adams, 1854			
Cylichna cylindracea (Pennant, 1777)	Gulf of Béjaïa	Bakalem, 2008	PO
Family Haminoeidae Pilsbry, 1895			
Roxaniella jeffreysi (Weinkauff, 1866)	NS	Pruvot-Fol, 1954	AM
Family Aglajidae Pilsbry, 1895 (1847)			
Philinopsis depicta (Renier, 1807)	Bay of Fetzara	Bakalem, 2008	AM
Family Alacuppidae Oskars, Bouchet & Malaquias, 2015			
Roxania semilaevis (G. Seguenza, 1880)	NS	Pruvot-Fol, 1954	AM
Family Laonidae Pruvot-Fol, 1954			
Laona pruinosa (W. Clark, 1827)	NS	Pruvot-Fol, 1954	BA
Family Philinidae J. E. Gray, 1850 (1815)			
Philine quadripartita Ascanius, 1772	Bay of Algiers; Gulf of Jijel; Bay of Fetzara	Bakalem, 2008	BA
Aplysiida			
Family Aplysiidae Lamarck, 1809			
Aplysia fasciata Poiret, 1789	NS	Pruvot-Fol, 1954	SA
	West coast of Algeria	Meziane *et al.*, 2020	
Aplysia punctata (Cuvier, 1803)	Annaba	Derbal & Kara, 2005	BA
	West coast of Algeria	Meziane *et al.*, 2020	
Bursatella leachii Blainville, 1817	El Kala	Refes *et al.*, 2010	PO
	Sidi Fredj	Eleftheriou *et al.*, 2011	
Dolabella auricularia ([Lightfoot], 1786)	l'île Plane	Brahimi & Bensaou, 2018	IP
Petalifera petalifera (Rang, 1828)	Castiglione	Dieuzeide, 1951	SA
Umbraculida			
Family Tylodinidae J. E. Gray, 1847			
Tylodina perversa (Gmelin, 1791)	NS	Pruvot-Fol, 1954	AM

(*i.e.*, Rhodopoidea, Acteonoidea, Ringiculimorpha, Pleurobranchida, Nudibranchia, Doridida, Cephalaspidea, Runcinida, Aplysiida, Pteropoda, Umbraculida, Sacoglossa, and Acochlidiimorpha) and considered informal (with the various constituent taxa currently placed within the subclass Heterobranchia), this group is still regarded as an unofficial whole by scholars and enthusiasts worldwide, who commonly refer to its members as "opisthobranchs", "marine heterobranchs", or "heterobranch sea slugs" (see Lombardo and Marletta, in press, for more details on the use of these informal terms). With their striking body shapes and unique adaptations, these marine creatures have garnered global attention and become particularly popular among underwater photography enthusiasts (Trainito & Doneddu, 2014; Lombardo & Marletta, in press).

With regard to the Algerian coast, the available data on these animals derive almost exclusively from reports included in general studies (Derbal & Kara, 2005; Bakalem, 2008; Refes *et al.,* 2010; CAR/ASPPLUE/PAM, 2015; Brahimi & Bensaou, 2018; Bensari *et al.,* 2020) and works dedicated to the malacofauna of specific areas (Meziane *et al.,* 2020). Historically, only five specialised studies have been dedicated to Algerian sea slugs (Dieuzeide, 1951; Pruvot-Fol, 1954; Camacho-García & Gosliner, 2008; Eleftheriou *et al.,* 2011; Tamsouri *et al.,* 2018). Moreover, these publications are almost entirely limited to records of individual species (Pruvot-Fol, 1954; Camacho-García & Gosliner, 2008; Eleftheriou *et al.,* 2011; Tamsouri *et al.,* 2018), and only one study (Dieuzeide, 1951) provides information extending beyond simple species reporting.

An examination of the records documented in the above-mentioned literature reveals that, prior to this study, 31 species of sea slugs were recorded in Algeria, belonging to seven higher-level taxa (one Acteonoidea, two Ringiculimorpha, eight Nudibranchia, six Doridida, eight Cephalaspidea, five Aplysiida, and one Umbraculida species) (Tab. 1). Given the limited and scattered information currently available on this group of molluscs in Algeria, our

Fig. 1: A: Position of the Mediterranean Sea on a global scale (white rectangle); B: location of the Algerian coastline within the Mediterranean Sea (white rectangle); C: location and coastal extent of the ten wilayas along the Algerian coast examined in this study.

Sl. 1: A: Položaj Sredozemskega morja v globalnem merilu (beli pravokotnik); B: lokacija alžirske obale znotraj Sredozemskega morja (beli pravokotnik); C: lokacija in obalni obseg desetih administrativnih predelov vzdolž alžirske obale, preučenih v tej študiji.

study aimed to compile the first checklist of Algerian sea slugs using new faunal data derived from both scientific research and contributions from Algerian enthusiasts. This list is intended to serve as a starting point and reference for future studies dedicated to sea slugs in Algeria.

MATERIAL AND METHODS

In compiling the faunal information presented in this study, a collection of photographic data obtained between 2010 to 2025 was used. These data were derived both from original field observations and from information provided by external contributors. In the former case, the data were collected through accidental capture (bycatch) of sea slugs in local fisheries (trammel nets, at depths ranging from 30 to 70 m) and through the manual collection of specimens during snorkelling sessions. Data from external contributors consisted of photographic material obtained from online reports and personal communications from enthusiasts and underwater photographers (see Tab. 2 and References). Overall, the data reported here were collected in ten wilayas (*i.e.*, provinces) along the Algerian coast, including Tlemcen, Aïn Témouchent, Oran, Mostaganem, Tipaza, Algiers, Boumerdès, Tizi Ouzou, Jijel, and Skikda (Fig 1).

Species identification was carried out by examining the photographic material available to

Tab. 2: Sea slug species documented from new data examined in this study. The symbol x indicates the presence of a given species in the corresponding wilaya. The symbols * and ‡ indicate the observation of egg mass(es) and mating activity, respectively. Sources of the records are provided in References. Chorotype abbreviations are as follows: ME = Mediterranean endemic; AM = Atlantic–Mediterranean; BA = Boreo-Atlantic; SA = subtropical Atlantic; IP = Indo-Pacific; PO = pan-oceanic; UD = Unknown distribution. Wilayas:1 = Tlemcen; 2 = Aïn Témouchent; 3 = Oran; 4 = Mostaganem; 5 = Tipaza; 6 = Algiers; 7 = Boumerdès; 8 = Tizi Ouzou; 9 = Jijel; 10 = Skikda.

Tab. 2: Vrste golih morskih polžev, dokumentirane na podlagi novih podatkov, preučenih v tej študiji. Simbol x označuje prisotnost določene vrste v pripadajočem administrativnem predelu. Simbola * in ‡ označujeta opažanje mrestov oziroma parjenja. Viri najdb so navedeni v literaturi. Kratice horotipov so naslednje: ME = sredozemski endemit; AM = atlantsko-sredozemski; BA = boreo-atlantski; SA = subtropski atlantski; IP = indo-pacifiški; PO = pan-oceanski; UD = neznana razširjenost. Administrativni predeli: 1 = Tlemcen; 2 = Aïn Témouchent; 3 = Oran; 4 = Mostaganem; 5 = Tipaza; 6 = Alžir; 7 = Boumerdès; 8 = Tizi Ouzou; 9 = Jijel; 10 = Skikda.

Taxon/wilaya	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Reference**	**Chorotype**
Pleurobranchida												
Family Pleurobranchidae Gray, 1827												
Pleurobranchus testudinarius Cantraine, 1835						x					Instagram, 2025c; present study	AM
Nudibranchia												
Family Aeolidiidae J. E. Gray, 1827												
Anteaeolidiella lurana (Ev. Marcus & Er. Marcus, 1967)			x								iNaturalist, 2024q; 2025l	PO
Spurilla neapolitana (Delle Chiaje, 1841)			x*			x					iNaturalist, 2024m; 2024o; 2025k; 2025m; present study	AM
Family Facelinidae Bergh, 1889												
Cratena peregrina (Gmelin, 1791)									x		Fates, pers. comm.	AM
Facelina rubrovittata (A. Costa, 1866)			x								iNaturalist, 2023d	ME
Family Flabellinidae Bergh, 1889												
Edmundsella pedata (Montagu, 1816)									x		Fates, pers. comm.; Azzoune pers. comm.; Mechekkef pers. comm.	BA
Flabellina affinis (Gmelin, 1791)							x‡		x		Fates, pers. comm.; Chibani, pers. comm.; Koudri, pers. comm.	AM
Paraflabellina ischitana (Y. Hirano & T. E. Thompson, 1990)	x										Zaoui, pers. comm.	AM
Family Glaucidae J. E. Gray, 1827												
Glaucus atlanticus Forster, 1777				x		x					Instagram, 2025a; present study	PO
Family Myrrhinidae Bergh, 1905												

Godiva quadricolor (Barnard, 1927)			x								iNaturalist, 2024p	PO
Family Samlidae Korshunova, Martynov, Bakken *et al.*, 2017												
Luisella babai (Schmekel, 1972)									x		Fates, pers. comm.	AM
Incertae sedis												
Eolid sp.			x								iNaturalist, 2025q	UD
Family Tethydidae Rafinesque, 1815												
Tethys fimbria Linnaeus, 1767						x					Instagram, 2024a; Present study	AM
Family Tritoniidae Lamarck, 1809												
Marionia blainvillea (Risso, 1818)						x					Present study	AM
Marionia cf. *gemmii* Almón, J. Pérez & Caballer, 2018						x					Instagram, 2025g	AM
Family Arminidae Iredale & O'Donoghue, 1923 (1841)												
Armina maculata Rafinesque, 1814						x					Instagram, 2023a; 2024c; 2025d; present study	AM
Family Janolidae Pruvot-Fol, 1933												
Antiopella cristata (Delle Chiaje, 1841)						x			x		Instagram, 2025f; Fates, pers. comm.	BA
Doridida												
Family Chromodorididae Bergh, 1891												
Felimare bilineata (Pruvot-Fol, 1953)									x		Fates, pers. comm.	AM
Felimare fontandraui (Pruvot-Fol, 1951)									x		Fates, pers. comm.	AM
Felimare picta (R. A. Philippi, 1836)	x‡					x	x		x		iNaturalist, 2022d; Instagram, 2025b; Fates, pers. comm.; Club ORCA, pers. comm.; Chibani, pers. comm.	SA
Felimare tricolor (Cantraine, 1835)						x			x		Instagram, 2024b; Fates, pers. comm.	AM
Felimare villafranca (Risso, 1818)									x		Fates, pers. comm.	AM
Felimida binza (Ev. Marcus & Er. Marcus, 1963)			x				x		x		iNaturalist, 2023c; Fates, pers. comm.; Chibani, pers. comm.	AM
Felimida elegantula (R. A. Philippi, 1844)									x		Koudri, pers. comm.	ME
Felimida luteorosea (Rapp, 1827)									x		Fates, pers. comm.	AM
Rudmania krohni (Verany, 1846)									x		Fates, pers. comm.	AM
Rudmania purpurea (Risso, 1831)			x						x‡		iNaturalist, 2022e; 2023b; Fates, pers. comm.	AM
Family Discodorididae Bergh, 1891												
Jorunna tomentosa (Cuvier, 1804)									x		Azzoune, pers. comm.	BA
Peltodoris atromaculata Bergh, 1880	x								x*‡		Club ORCA, pers. comm.; Fates, pers. comm.	AM
Platydoris argo (Linnaeus, 1767)					x				x*		Fates, pers. comm.; present study	AM
Tayuva maculosa (Bergh, 1884)								x			Present study	ME
Family Calycidorididae Roginskaya, 1972												
Diaphorodoris papillata Portmann & Sandmeier, 1960									x		Azzoune, pers. comm.	AM
Family Dendrodorididae O'Donoghue, 1924 (1864)												
Dendrodoris limbata (Cuvier, 1804)									*		Fates, pers. comm.	AM
Family Polyceridae Alder & Hancock, 1845												
Martadoris mediterranea (M. Domínguez, Pola & Ramón, 2015)									x		Fates, pers. comm.	ME
Cephalaspidea												
Family Haminoeidae Pilsbry, 1895												

Haminoea exigua (Schaefer, 1992)			x								iNaturalist, 2024s	ME
Lamprohaminoea ovalis (Pease, 1868)									x		Fates, pers. comm.	IP
Aplysiida												
Family Aplysiidae Lamarck, 1809												
Aplysia dactylomela Rang, 1828						x			x‡		iNaturalist, 2022f; 2024u	SA
Aplysia depilans Gmelin, 1791			x			x*‡			x		iNaturalist, 2022b; 2024u; 2025g; 2025p; 2025r	AM
Aplysia fasciata Poiret, 1789			x			x			x	x	iNaturalist, 2020; 2025h; 2025j; Fates, pers. comm.	SA
Aplysia punctata (Cuvier, 1803)			x								iNaturalist, 2021; 2023a; 2024n; 2025i	BA
Aplysia sp.			*					x?			iNaturalist, 2024h; 2024v; 2025c; 2025s	UD
Aplysia sp. 2 (see Lombardo & Marletta, in press)			x*						x		iNaturalist, 2025a; 2025d; 2025e; 2025g; Fates, pers. comm.	UD
Aplysia sp. 3 (see Lombardo & Marletta, in press)			x								iNaturalist, 2024t	UD
Petalifera petalifera (Rang, 1828)			x								iNaturalist, 2024a	SA
Pteropoda												
Family Cymbuliidae J. E. Gray, 1840												
Cymbulia peronii Blainville, 1818		x			x						present study	SA
Umbraculida												
Family Tylodinidae J. E. Gray, 1847												
Tylodina perversa (Gmelin, 1791)									x		Fates, pers. comm.	AM
Family Umbraculidae Dall, 1889 (1827)												
Umbraculum umbraculum ([Lightfoot], 1786)						x			x		Instagram, 2024d; 2025e; Fates, pers. comm.; present study	PO
Sacoglossa												
Family Oxynoidae Stoliczka, 1868 (1847)												
Lobiger serradifalci (Calcara, 1840)			x								iNaturalist, 2024e; 2024g	AM
Oxynoe olivacea Rafinesque, 1814			x								iNaturalist, 2023g; 2024b; 2024c; 2024d; 2024f	ME
Family Plakobranchidae J. E. Gray, 1840												
Elysia sp.									*		Fates, pers. comm.	UD
Elysia timida (Risso, 1818)			x						x		iNaturalist, 2024i; 2024j; 2024k; 2024l; 2024r; 2025n; 2025o; Fates, pers. comm.	SA
Thuridilla hopei (Vérany, 1853)			x		x				x		iNaturalist, 2022c; 2023e; 2023f; present study	AM
Family Limapontiidae J. E. Gray, 1847												
Placida cremoniana (Trinchese, 1892)								x			Present study	AM
Placida dendritica (Alder & Hancock, 1843)			x								iNaturalist, 2022a	PO
Species per wilaya	3	1	20	1	3	14	3	3	31	1		
Species total	54											
Families per wilaya	3	1	9	1	3	10	2	3	14	1		
Families total	24											

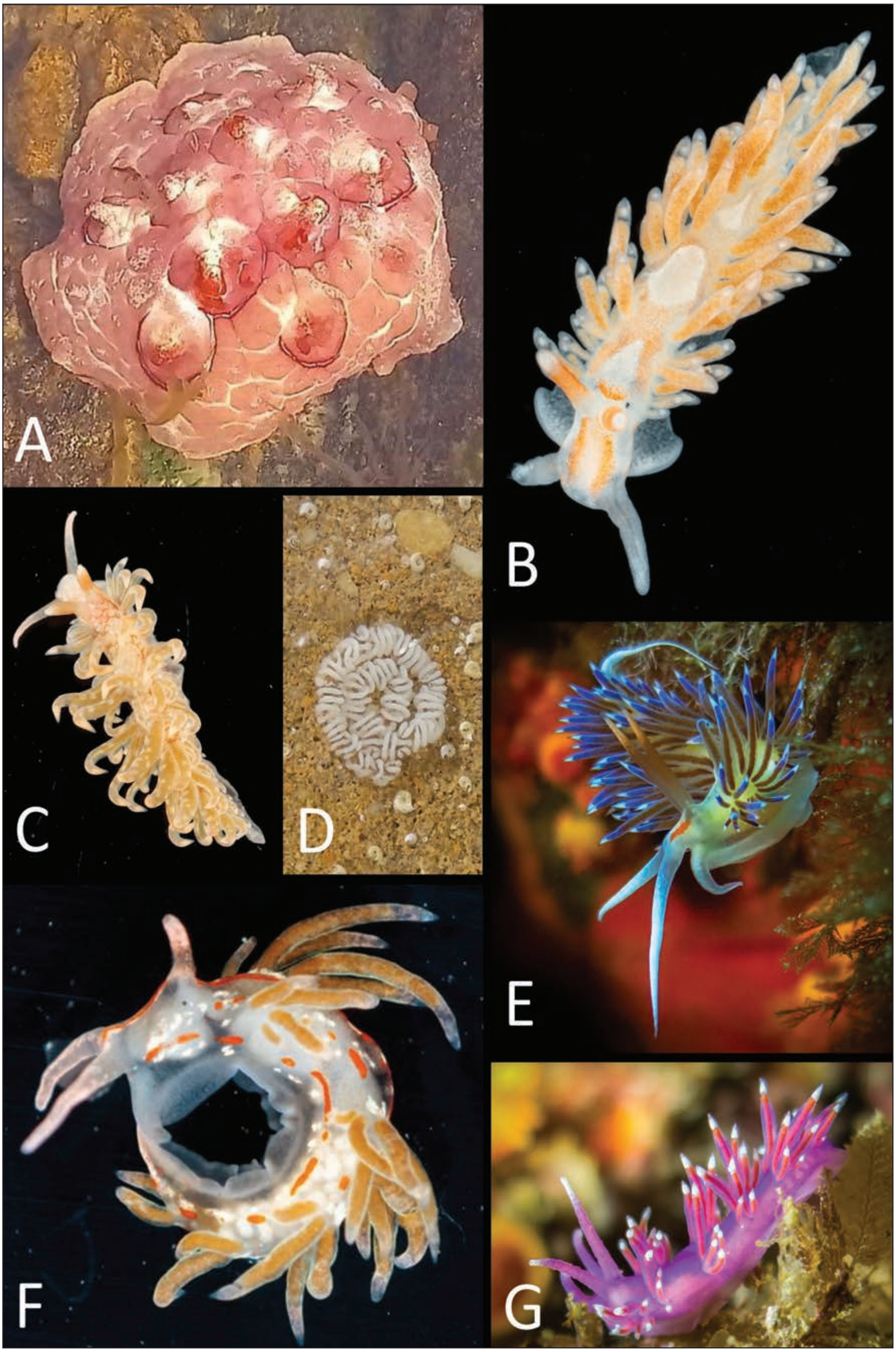

Fig. 2: A: *Pleurobranchus testudinarius*; **B:** *Anteaeolidiella lurana*; **C:** *Spurilla neapolitana*; **D:** *S. neapolitana*, **egg mass; E:** *Cratena peregrina*; **F:** *Facelina rubrovittata*; **G:** *Edmundsella pedata*. **Photos by J. Chabane (A), H. S. Kernane (B–D, F), and Y. Fates (E, G).**

Sl. 2: A: *Pleurobranchus testudinarius*; **B:** *Anteaeolidiella lurana*; **C:** *Spurilla neapolitana*; **D:** *S. neapolitana*, **mrest; E:** *Cratena peregrina*; **F:** *Facelina rubrovittata*; **G:** *Edmundsella pedata*. **Fotografije: J. Chabane (A), H. S. Kernane (B–D, F), in Y. Fates (E, G).**

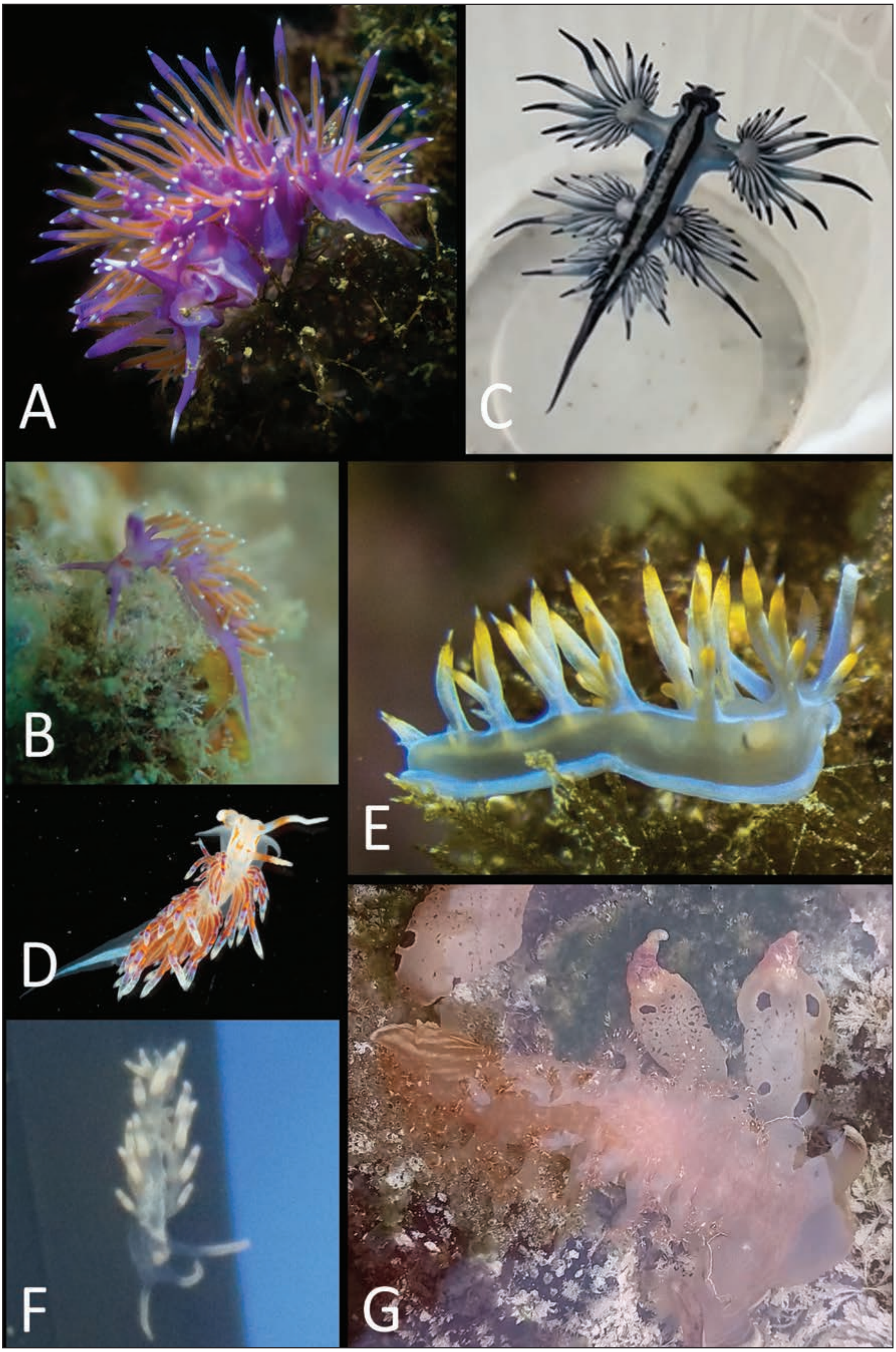

Fig. 3: A: *Flabellina affinis*; **B:** *Paraflabellina ischitana*; **C:** *Glaucus atlanticus*; **D:** *Godiva quadricolor*; **E:** *Luisella babai*; **F: Eolid sp.; G:** *Tethys fimbria*. **Photos by Y. Fates (A, E), S. Zaoui (B), H. O. Mensous (C), H. S. Kernane (D, F), and M. Tacheboubet (G).**

Sl. 3: A: *Flabellina affinis*; **B:** *Paraflabellina ischitana*; **C:** *Glaucus atlanticus*; **D:** *Godiva quadricolor*; **E:** *Luisella babai*; **F: Eolid sp.; G:** *Tethys fimbria*. **Fotografije: Y. Fates (A, E), S. Zaoui (B), H. O. Mensous (C), H. S. Kernane (D, F), in M. Tacheboubet (G).**

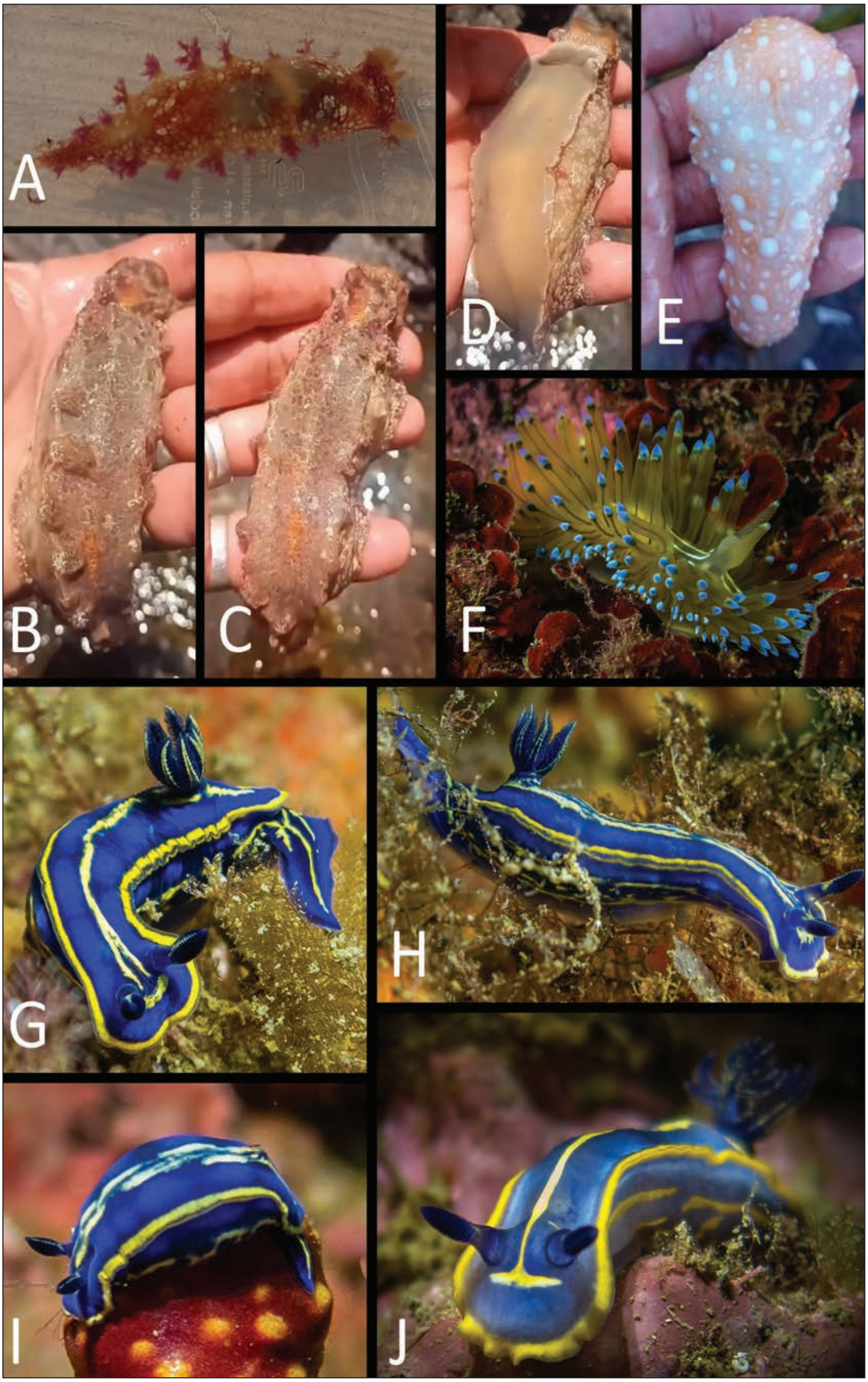

Fig. 4: A: *Marionia blainvillea*; **B:** *Marionia* **cf.** *gemmii*, **dorsal view; C:** *M.* **cf.** *gemmii*, **additional dorsal view; D:** *M.* **cf.** *gemmii*, **left ventral-lateral view; E:** *Armina maculata*; **F:** *Antiopella cristata*; **G:** *Felimare bilineata*; **H:** *F. bilineata*, **slightly different chromatic pattern; I:** *F. bilineata*, **additional specimen; J:** *F. fontandraui*. **Photos by J. Chabane (A), M. Tacheboubet (B–E), and Y. Fates (F–J).**

Sl. 4: A: *Marionia blainvillea*; **B:** *Marionia* **cf.** *gemmii*, **hrbtni pogled; C:** *M.* **cf.** *gemmii*, **dodatni hrbtni pogled; D:** *M.* **cf.** *gemmii*, **levi trebušno-bočni pogled; E:** *Armina maculata*; **F:** *Antiopella cristata*; **G:** *Felimare bilineata*; **H:** *F. bilineata*, **nekoliko drugačen barvni vzorec; I:** *F. bilineata*, **dodaten primerek; J:** *F. fontandraui*. **Fotografije: J. Chabane (A), M. Tacheboubet (B–E), in Y. Fates (F–J).**

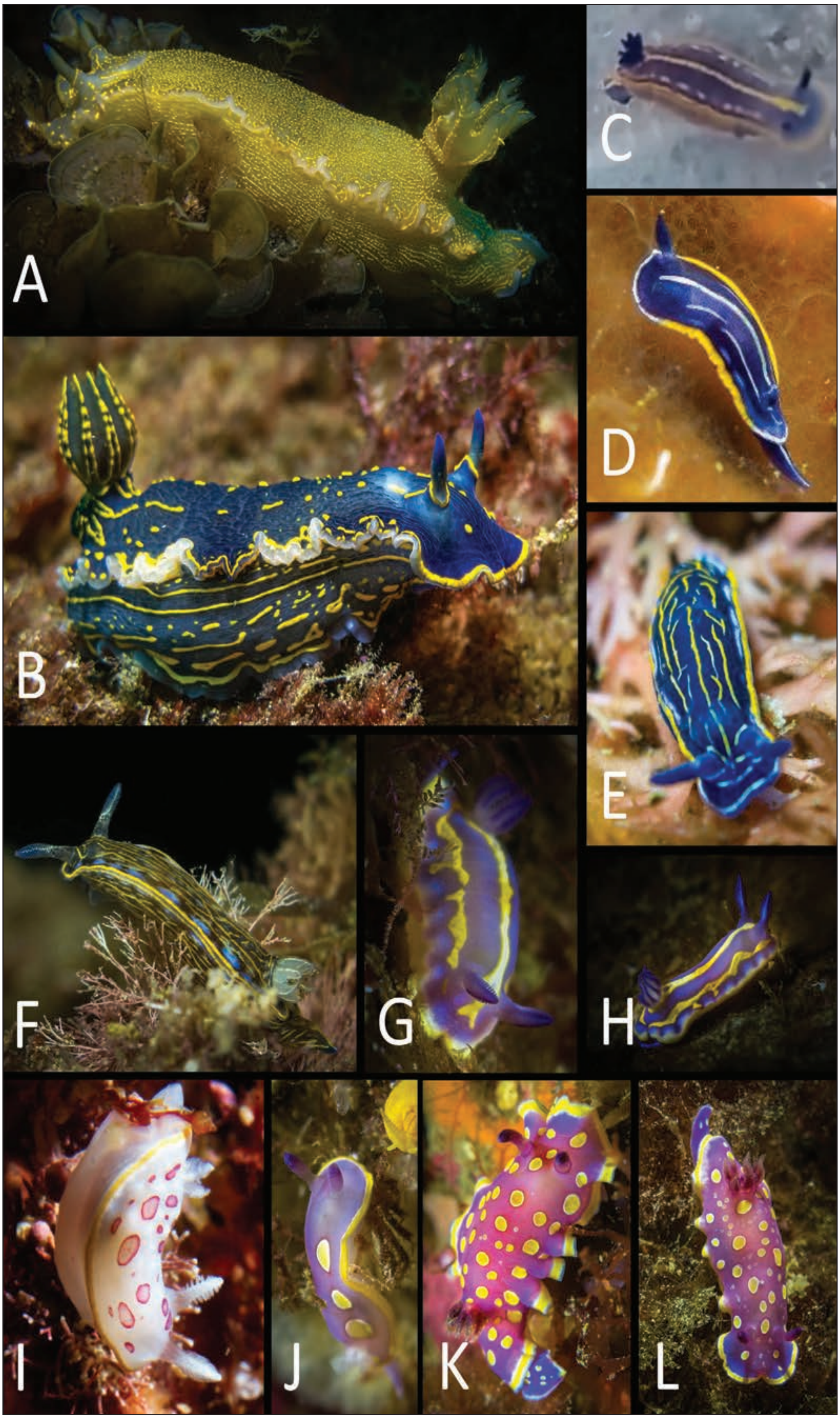

Fig. 5: A: *Felimare picta*, **green-yellow coloration; B:** *F. picta*, **blue-yellow coloration; C:** *F. tricolor*; **D:** *F. villafranca*, **juvenile specimen; E:** *F. villafranca*, **less developed adult chromatic pattern; F:** *F. villafranca*; **G:** *Felimida binza*, **adult specimen; H:** *F. binza*, **slightly more developed adult chromatic pattern; I:** *Felimida elegantula*; **J:** *F. luteorosea*, **intermediate adult specimen; K**: *F. luteorosea*, **adult specimen; L:** *F. luteorosea*, **more developed adult chromatic pattern. Photos by Y. Fates (A–B, D–H, J–L), M. Tacheboubet (C), and H. Koudri (I).**

Sl. 5: A: *Felimare picta*, **zeleno-rumena obarvanost; B:** *F. picta*, **modro-rumena obarvanost; C:** *F. tricolor*; **D:** *F. villafranca*, **mladostni primerek; E:** *F. villafranca*, **slabše razvit barvni vzorec pri odraslih; F:** *F. villafranca*; **G:** *Felimida binza*, **odrasel primerek; H:** *F. binza*, **malo bolj razvit odrasli barvni vzorec; I:** *Felimida elegantula*; **J:** *F. luteorosea*, **vmesni odrasel primerek; K**: *F. luteorosea*, **odrasel primerek; L:** *F. luteorosea*, **bolj razvit odrasli barvni vzorec. Fotografije Y. Fates (A–B, D–H, J–L), M. Tacheboubet (C), in H. Koudri (I).**

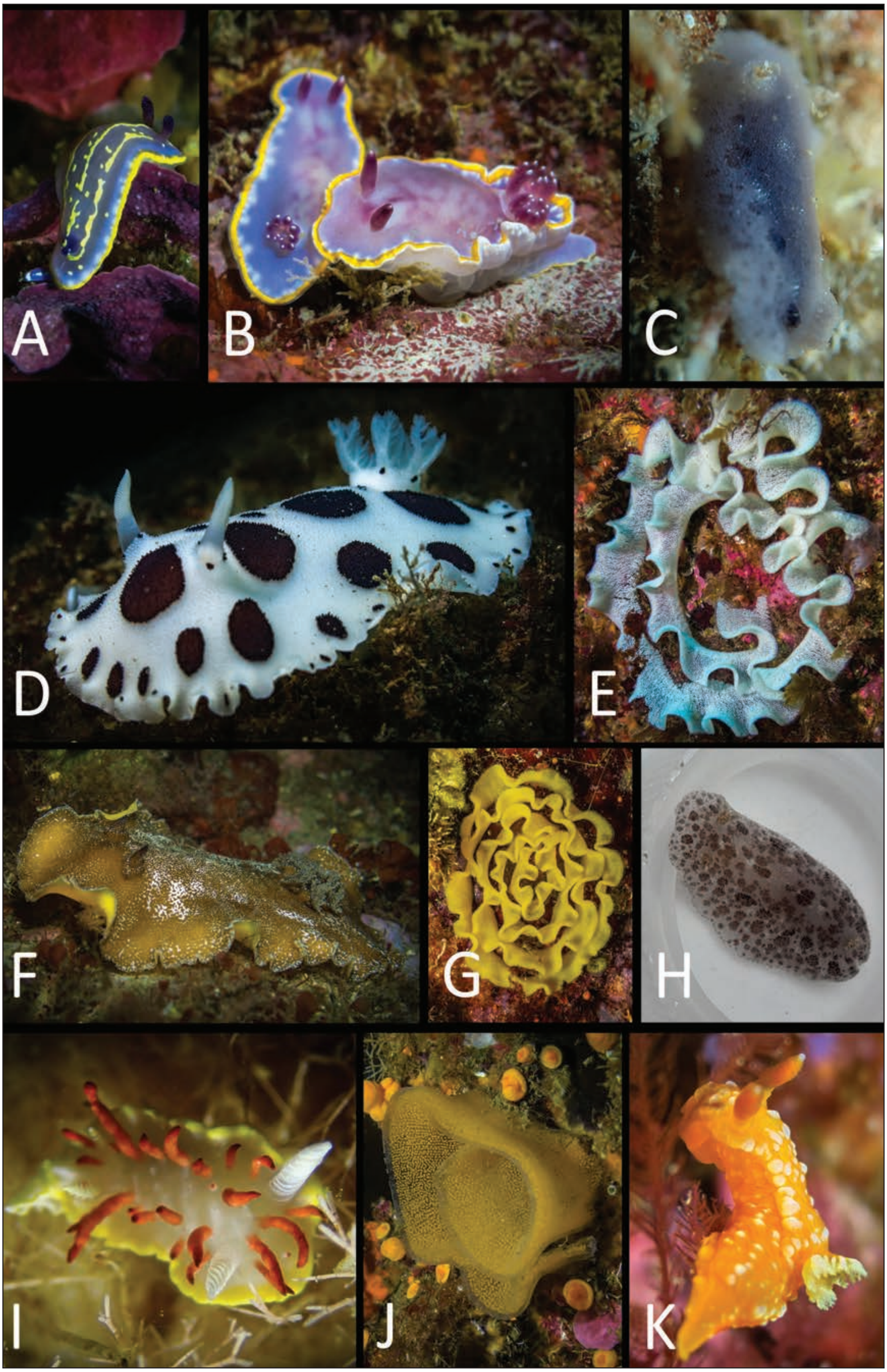

Fig. 6: A: *Rudmania krohni*; **B:** *R. purpurea*, **two specimens; C:** *Jorunna tomentosa*; **D:** *Peltodoris atromaculata*; **E:** *P. atromaculata*, **egg mass; F:** *Platydoris argo*; **G:** *P. argo*, **egg mass;** H: *Tayuva maculosa*; **I:** *Diaphorodoris papillata*; **J:** *Dendrodoris limbata*, **egg mass; K:** *Martadoris mediterranea*. **Photos by Y. Fates (A–B, D–H, J–K), and F. Azzoune (C, I).**

Sl. 6: A: *Rudmania krohni*; **B:** *R. purpurea*, **dva primerka; C:** *Jorunna tomentosa*; **D:** *Peltodoris atromaculata*; **E:** *P. atromaculata*, **mrest; F:** *Platydoris argo*; **G:** *P. argo*, **mrest;** H: *Tayuva maculosa*; **I:** *Diaphorodoris papillata*; **J:** *D. limbata*, **mrest; K:** *Martadoris mediterranea*. ***Fotografije*: Y. Fates (A–B, D–H, J–K), in F. Azzoune (C, I).**

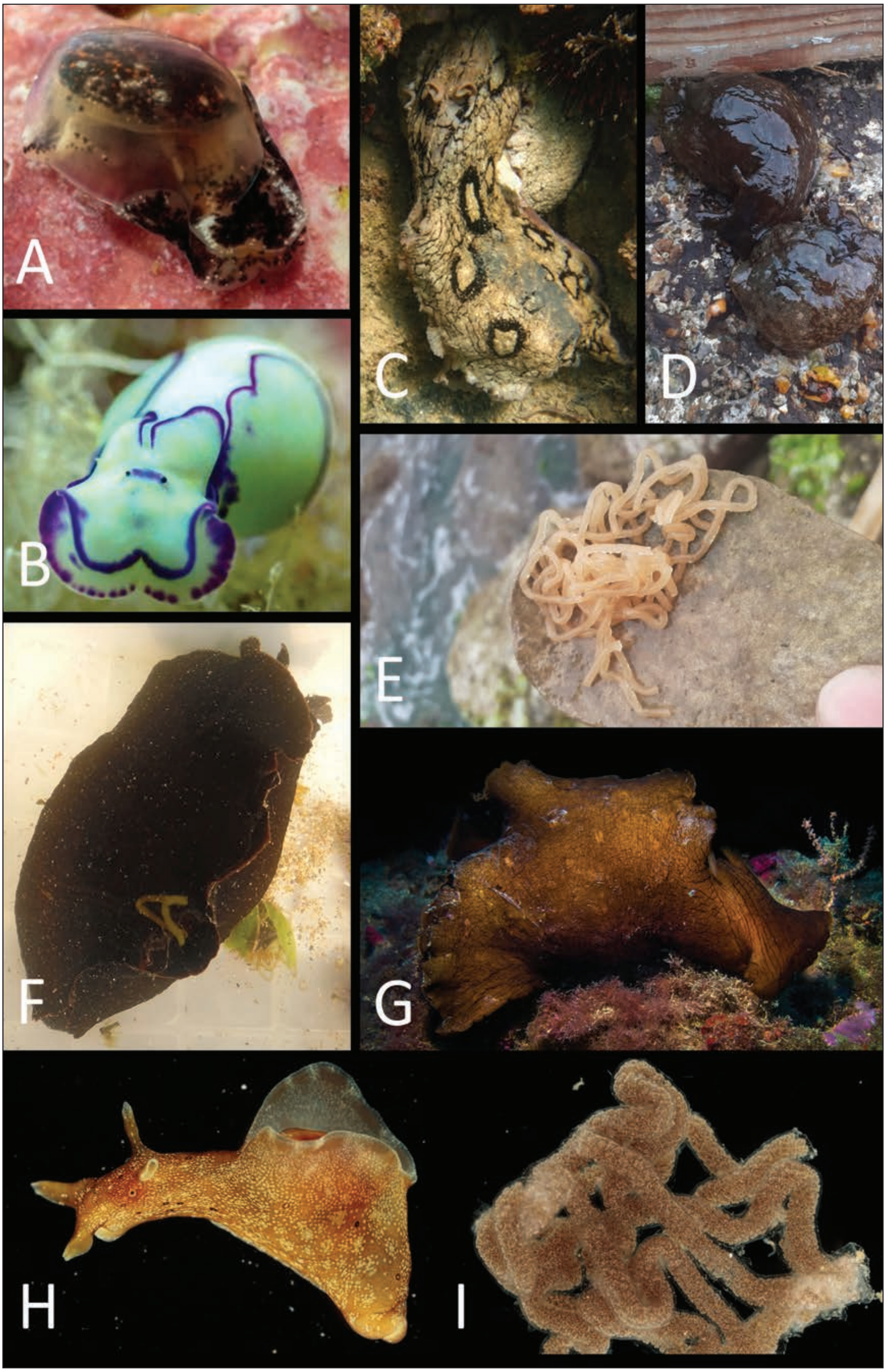

***Fig. 7*: A:** *Haminoea exigua*; **B:** *Lamprohaminoea ovalis*; **C:** *Aplysia dactylomela*, ***two specimens mating*; D:** *A. depilans*; **E:** *A. depilans*, **egg mass; F:** *A. fasciata*, ***black morphotype*; G:** *A. fasciata*, ***brown/massive morphotype*; H:** *A. punctata*; **I:** *Aplysia* **sp., egg mass. Photos by H. S. Kernane (A, F, H–I), Y. Fates (B, G), A. Dria (C), and J. Chabane (D–E).**

***Sl. 7*: A:** *Haminoea exigua*; **B:** *Lamprohaminoea ovalis*; **C:** *Aplysia dactylomela*, ***primerka na parjenju*; D:** *A. depilans*; **E:** *A. depilans*, **mrest; F:** *A. fasciata*, ***črni morfotip*; G:** *A. fasciata*, ***rjavi/čokati morfotip*; H:** *A. punctata*; **I:** *Aplysia* **sp., mrest. Fotografije: H. S. Kernane (A, F, H–I), Y. Fates (B, G), A. Dria (C), in J. Chabane (D–E).**

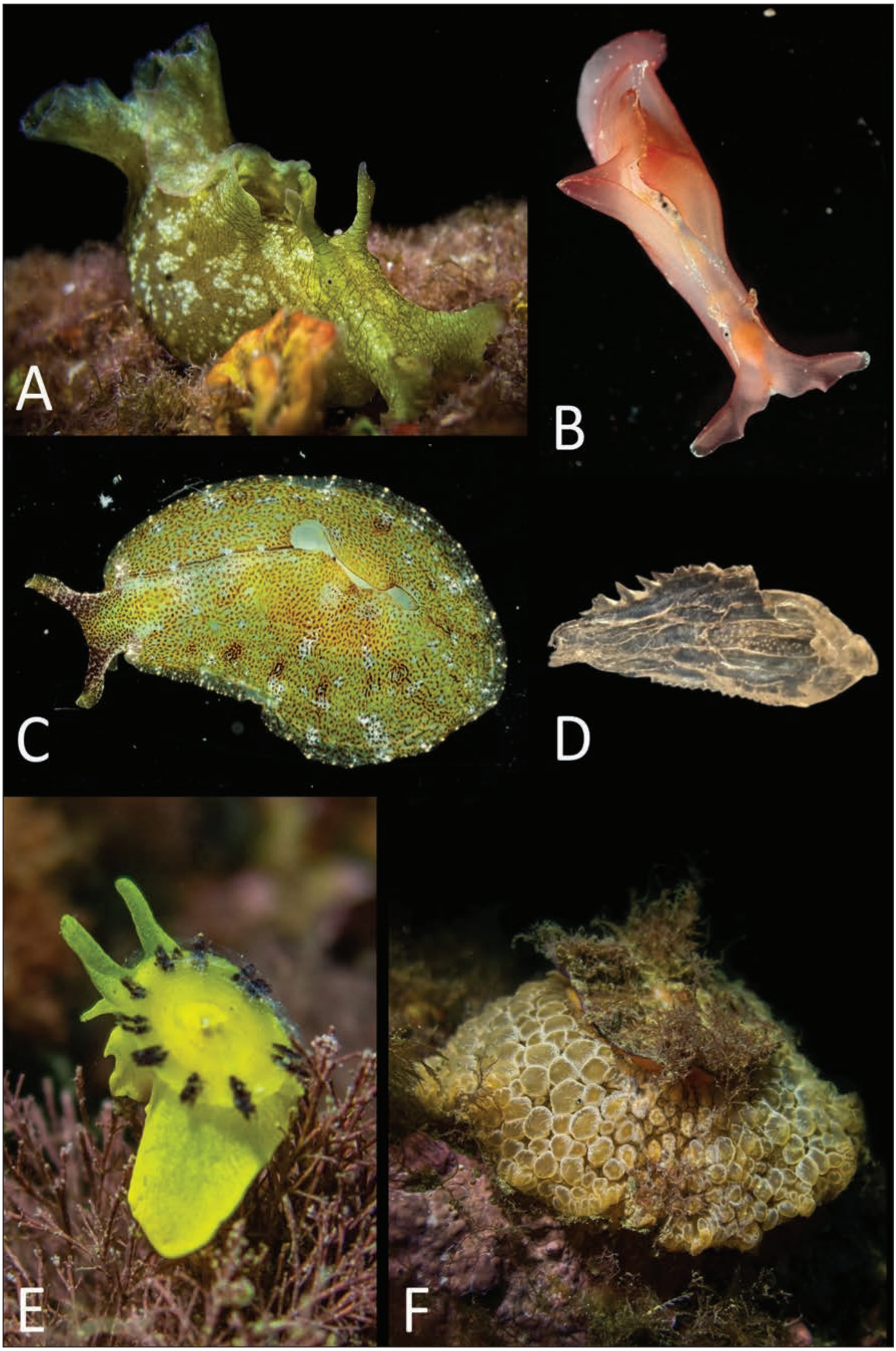

Fig. 8: A: *Aplysia* ***sp. 2; B:*** *Aplysia* ***sp. 3; C:*** *Petalifera petalifera;* ***D:*** *Cymbulia peronii pseudoconcha;* ***E:*** *Tylodina perversa;* ***F:*** *Umbraculum umbraculum.* ***Photos by Y. Fates (A, E–F), H. S. Kernane (B–C), and J. Chabane (D).***

Sl. 8: A: *Aplysia* ***sp. 2; B:*** *Aplysia* ***sp. 3; C:*** *Petalifera petalifera;* ***D:*** *Cymbulia peronii pseudoconcha;* ***E:*** *Tylodina perversa;* ***F:*** *Umbraculum umbraculum.* ***Fotografije: Y. Fates (A, E–F), H. S. Kernane (B–C), in J. Chabane (D).***

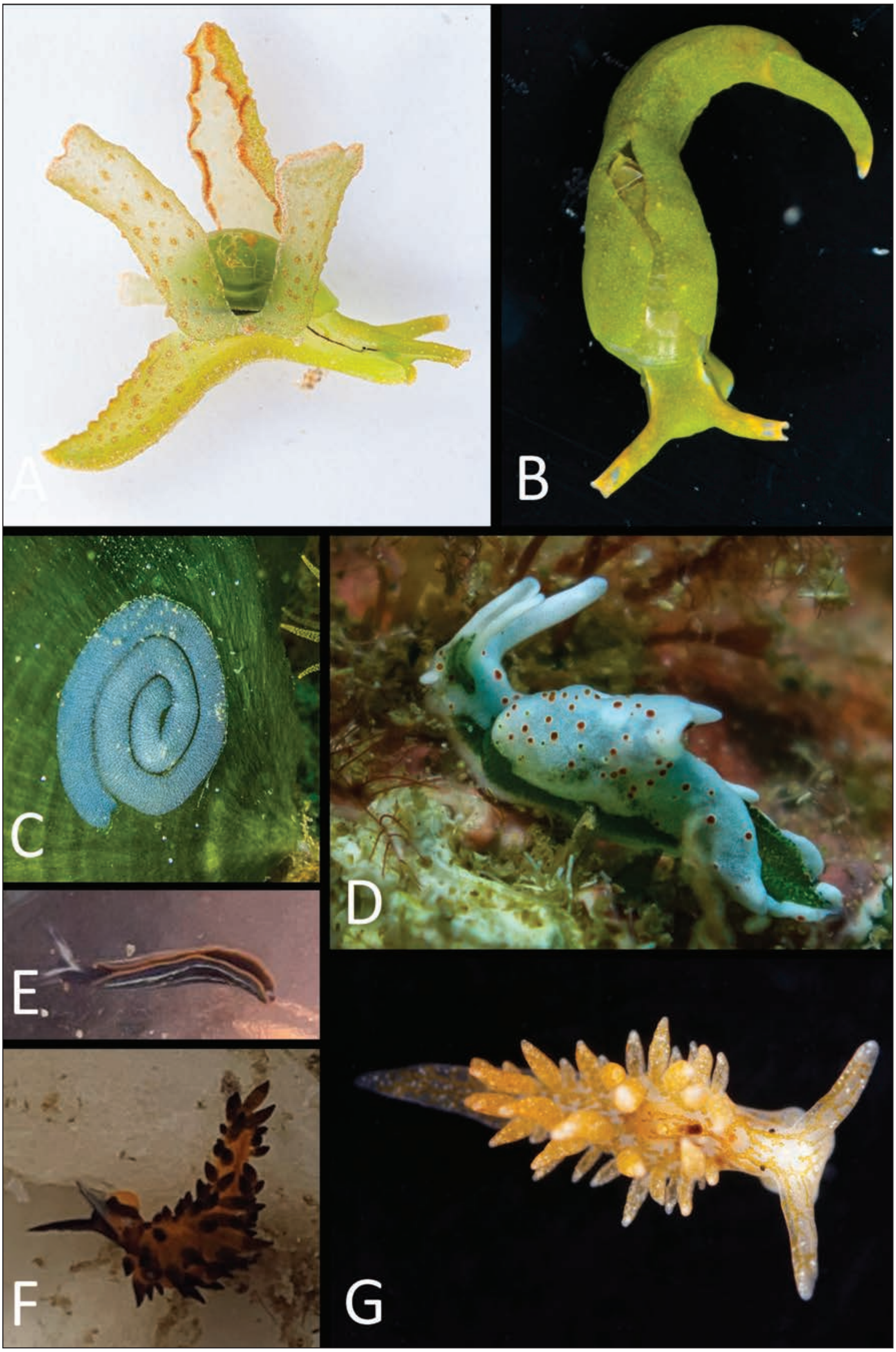

Fig. 9. A: *Lobiger serradifalci*; ***B:*** *Oxynoe olivacea*; ***C:*** *Elysia* **sp., egg mass; *D:*** *Elysia timida*; ***E:*** *Thuridilla hopei*; ***F:*** *Placida cremoniana*; ***G:*** *Placida dendritica*. **Photos by H. S. Kernane (A–B, G), Y. Fates (C–D), and J. Chabane (E–F).**

Sl. 9: A: *Lobiger serradifalci*; ***B:*** *Oxynoe olivacea*; ***C:*** *Elysia* **sp., jajčna masa; *D:*** *Elysia timida*; ***E:*** *Thuridilla hopei*; ***F:*** *Placida cremoniana*; ***G:*** *Placida dendritica*. **Fotografije: H. S. Kernane (A–B, G), Y. Fates (C–D), in J. Chabane (E–F).**

the authors, using relevant literature and online resources (Van Der Spoel, 1976; Cervera *et al.*, 1986; 1998; Hirano & Thompson, 1990; Rudman 1998–2010; Ballesteros *et al.*, 2012–2026; Calado & Silva, 2012; Trainito & Doneddu, 2014; Domínguez *et al.*, 2015; Martínez Chacón, 2018; Pérez-Dieste *et al.*, 2021; Rufray *et al.*, 2021; Lombardo & Marletta, in press). In addition, the chorotype was provided for each species (Tab. 1–2). The chorotype of each species, based on the definitions provided in Bianchi *et al.* (2012) (with the additional category of "UD" for species whose distribution is unknown), was determined from pertinent literature and online resources (Van Der Spoel, 1976; Ballesteros *et al.*, 2012–2026; Trainito & Doneddu, 2014; Kapeller, 2026; Lombardo & Marletta, in press).

RESULTS

The examination of photographic data analysed in the present study revealed the presence of 54 sea slug species along the Algerian coastline belonging to eight higher-level taxa (Tab. 2) (Figs. 2–9). The most diverse were the Doridida (17 species, 5 families) and Nudibranchia (16, 10), followed by Aplysiida (8, 1) and Sacoglossa (7, 3). The least diverse were the Umbraculida (2 species, 2 families), Cephalaspidea (2, 1), Pleurobranchida (1, 1), and Pteropoda (1, 1) (Fig. 10A). Of the 54 species documented in this study, 40 are newly recorded for the area of the Algerian coast, specifically: one Pleurobranchida (*Pleurobranchus testudinarius*), 11 Nudibranchia (*Anteaeolidiella lurana*, *Spurilla*

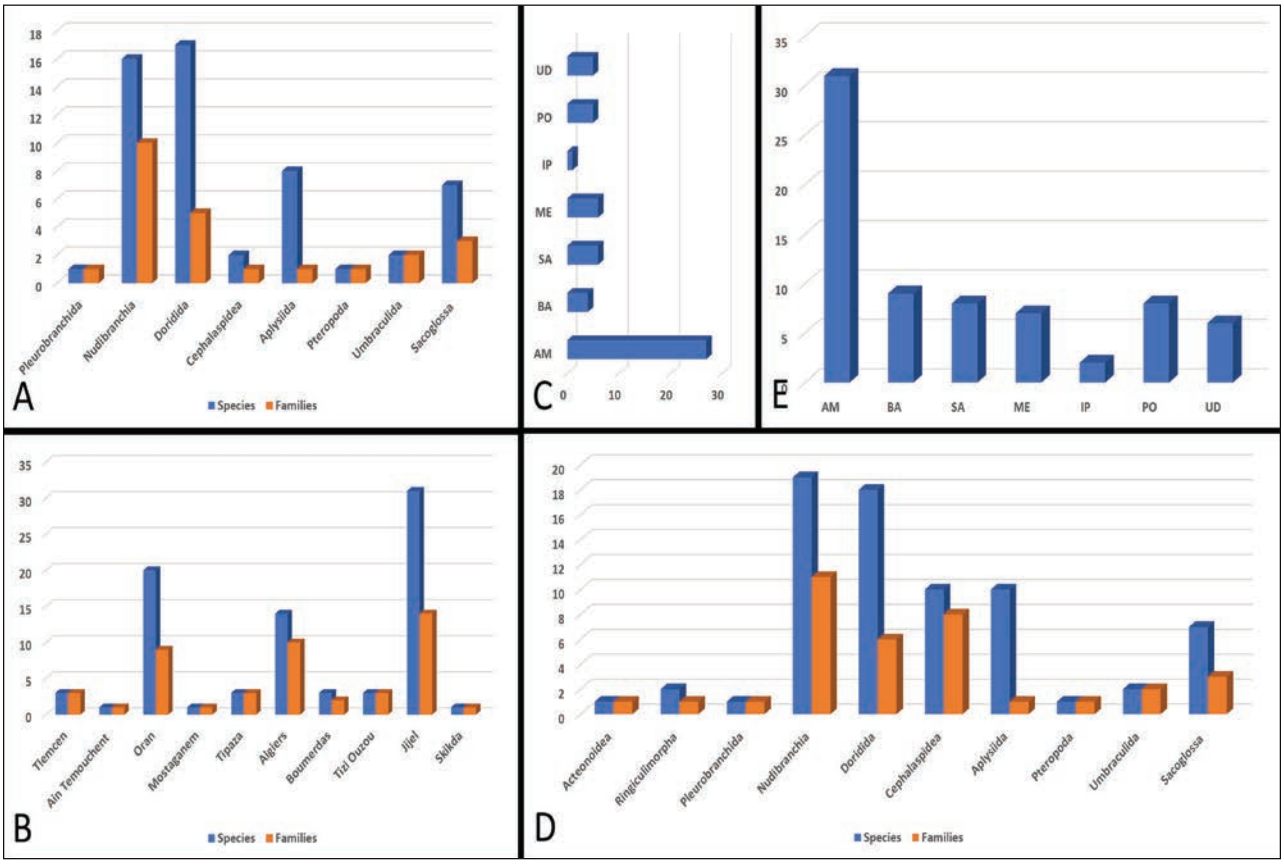

Fig. 10: A: Number of species and families per taxon documented in this study; B: number of species and families recorded in the ten wilayas examined; C: distribution of species chorotypes in the present study; D: number of species and families per taxon recorded along the Algerian coast (based on literature data and present study); E: distribution of species chorotypes along the Algerian coast (based on literature data and present study).

Sl. 10: A: Število vrst in število družin po taksonih ugotovljenih v tej raziskavi; B: število vrst in število družin v desetih administrativnih predelih, C: razširjenost horotipov v pričujoči študiji; D: število vrst in število družin po taksonih ugotovljenih vzdolž alžirske obale (na podlagi literaturnih podatkov in pričujoče raziskave); E: Razširjenost horotipov vzdolž alžirske obale (na podlagi podatkov iz literature in pričujoče študije).

Tab. 3. Complete list (literature data plus present study) of sea slugs recorded along the Algerian coast to date.
Tab. 3. Celoten seznam (podatki iz literature in pričujoče študije) golih morskih polžev, zabeleženih vzdolž alžirske obale do danes.

Taxon	**Species**	**Family**
Acteonoidea	**1**	**1**
Family Acteonidae A. d'Orbigny, 1842		
Acteon tornatilis (Linnaeus, 1758)		
Ringiculimorpha	**2**	**1**
Family Ringiculidae R. A. Philippi, 1853		
Ringicula buccinea (Brocchi, 1814)		
Ringicula sp.		
Pleurobranchida	**1**	**1**
Family Pleurobranchidae Gray, 1827		
Pleurobranchus testudinarius Cantraine, 1835		
Nudibranchia	**19**	**11**
Family Aeolidiidae J. E. Gray, 1827		
Anteaeolidiella lurana (Ev. Marcus & Er. Marcus, 1967)		
Spurilla neapolitana (Delle Chiaje, 1841)		
Family Facelinidae Bergh, 1889		
Cratena peregrina (Gmelin, 1791)		
Facelina auriculata (O. F. Müller, 1776)		
Facelina rubrovittata (A. Costa, 1866)		
Family Flabellinidae Bergh, 1889		
Edmundsella pedata (Montagu, 1816)		
Flabellina affinis (Gmelin, 1791)		
Paraflabellina ischitana (Y. Hirano & T. E. Thompson, 1990)		
Family Glaucidae J. E. Gray, 1827		
Glaucus atlanticus Forster, 1777		
Family Myrrhinidae Bergh, 1905		
Godiva quadricolor (Barnard, 1927)		
Nemesignis banyulensis (Portmann & Sandmeier, 1960)		
Family Fionidae J. E. Gray, 1857		
Fiona pinnata (Eschscholtz, 1831)		
Family Samlidae Korshunova, Martynov, Bakken *et al.*, 2017		
Luisella babai (Schmekel, 1972)		

Incertae sedis		
Eolid sp.		
Family Tethydidae Rafinesque, 1815		
Tethys fimbria Linnaeus, 1767		
Family Tritoniidae Lamarck, 1809		
Marionia blainvillea (Risso, 1818)		
Marionia cf. *gemmii* Almón, J. Pérez & Caballer, 2018		
Family Arminidae Iredale & O'Donoghue, 1923 (1841)		
Armina maculata Rafinesque, 1814		
Family Janolidae Pruvot-Fol, 1933		
Antiopella cristata (Delle Chiaje, 1841)		
Doridida	**18**	**6**
Family Chromodorididae Bergh, 1891		
Felimare bilineata (Pruvot-Fol, 1953)		
Felimare fontandraui (Pruvot-Fol, 1951)		
Felimare picta (R. A. Philippi, 1836)		
Felimare tricolor (Cantraine, 1835)		
Felimare villafranca (Risso, 1818)		
Felimida binza (Ev. Marcus & Er. Marcus, 1963)		
Felimida elegantula (R. A. Philippi, 1844)		
Felimida luteorosea (Rapp, 1827)		
Rudmania krohni (Verany, 1846)		
Rudmania purpurea (Risso, 1831)		
Family Discodorididae Bergh, 1891		
Jorunna tomentosa (Cuvier, 1804)		
Peltodoris atromaculata Bergh, 1880		
Platydoris argo (Linnaeus, 1767)		
Tayuva maculosa (Bergh, 1884)		
Family Dorididae Rafinesque, 1815		
Doris verrucosa Linnaeus, 1758		
Family Calycidorididae Roginskaya, 1972		
Diaphorodoris papillata Portmann & Sandmeier, 1960		
Family Dendrodorididae O'Donoghue, 1924 (1864)		
Dendrodoris limbata (Cuvier, 1804)		

Family Polyceridae Alder & Hancock, 1845		
Martadoris mediterranea (M. Domínguez, Pola & Ramón, 2015)		
Cephalaspidea	**10**	**8**
Family Bullidae J. E. Gray, 1827		
Bulla striata Bruguière, 1792		
Family Retusidae Thiele, 1925		
Retusa variabilis (Milaschewitsch, 1912)		
Family Cylichnidae H. Adams & A. Adams, 1854		
Cylichna cylindracea (Pennant, 1777)		
Family Haminoeidae Pilsbry, 1895		
Haminoea exigua (Schaefer, 1992)		
Lamprohaminoea ovalis (Pease, 1868)		
Roxaniella jeffreysi (Weinkauff, 1866)		
Family Aglajidae Pilsbry, 1895 (1847)		
Philinopsis depicta (Renier, 1807)		
Family Alacuppidae Oskars, Bouchet & Malaquias, 2015		
Roxania semilaevis (G. Seguenza, 1880)		
Family Laonidae Pruvot-Fol, 1954		
Laona pruinosa (W. Clark, 1827)		
Family Philinidae J. E. Gray, 1850 (1815)		
Philine quadripartita Ascanius, 1772		
Aplysiida	**10**	**1**
Family Aplysiidae Lamarck, 1809		
Aplysia dactylomela Rang, 1828		
Aplysia depilans Gmelin, 1791		
Aplysia fasciata Poiret, 1789		
Aplysia punctata (Cuvier, 1803)		
Aplysia sp.		
Aplysia sp. 2 (see Lombardo & Marletta, in press)		
Aplysia sp. 3 (see Lombardo & Marletta, in press)		
Bursatella leachii Blainville, 1817		
Dolabella auricularia ([Lightfoot], 1786)		
Petalifera petalifera (Rang, 1828)		
Pteropoda	**1**	**1**

Family Cymbuliidae J. E. Gray, 1840		
Cymbulia peronii Blainville, 1818		
Umbraculida	**2**	**2**
Family Tylodinidae J. E. Gray, 1847		
Tylodina perversa (Gmelin, 1791)		
Family Umbraculidae Dall, 1889 (1827)		
Umbraculum umbraculum ([Lightfoot], 1786)		
Sacoglossa	**7**	**3**
Family Oxynoidae Stoliczka, 1868 (1847)		
Lobiger serradifalci (Calcara, 1840)		
Oxynoe olivacea Rafinesque, 1814		
Family Plakobranchidae J. E. Gray, 1840		
Elysia sp.		
Elysia timida (Risso, 1818)		
Thuridilla hopei (Vérany, 1853)		
Family Limapontiidae J. E. Gray, 1847		
Placida cremoniana (Trinchese, 1892)		
Placida dendritica (Alder & Hancock, 1843)		
Total species and families	**71**	**35**

neapolitana, *Facelina rubrovittata*, *Edmundsella pedata*, *Paraflabellina ischitana*, *Glaucus atlanticus*, Eolid sp., *Marionia blainvillea*, *Marionia* cf. *gemmii*, *Armina maculata*, and *Antiopella cristata*), 12 Doridida (*Felimare bilineata*, *F. fontandraui*, *F. picta*, *F. villafranca*, *Felimida binza*, *F. elegantula*, *F. luteorosea*, *Rudmania krohni*, *Tayuva maculosa*, *Diaphorodoris papillata*, *Dendrodoris limbata*, and *Martadoris mediterranea*), two Cephalaspidea (*Haminoea exigua* and *Lamprohaminoea ovalis*), five Aplysiida (*Aplysia dactylomela*, *A. depilans*, *Aplysia* sp., *Aplysia* sp. 2, and *Aplysia* sp. 3), one Pteropoda (*Cymbulia peronii*), one Umbraculida (*Umbraculum umbraculum*), and seven Sacoglossa (*Lobiger serradifalci*, *Oxynoe olivacea*, *Elysia* sp., *E. timida*, *Thuridilla hopei*, *Placida cremoniana*, and *Placida dendritica*).

With regard to the wilayas covered by the data collection, Jijel (31 species, 14 families), Oran (20, 9), and Algiers (14, 10) showed the highest diversity. In contrast, the remaining wilayas exhibited generally low diversity: Tizi Ouzou (4 species, 3 families), Tlemcen (3, 3), Tipaza (3, 3), Boumerdès (3, 2), Aïn Témouchent (1, 1), Mostaganem (1, 1), and Skikda (1, 1) (Fig. 10B).

Examining the chorotypes of the documented species, a marked dominance of the species with Atlantic–Mediterranean distribution was observed (27 species), compared to those with other chorotypes, *i.e.*, subtropical Atlantic (6), Mediterranean endemic (6), pan-oceanic (5), Boreo-Atlantic (4), and Indo-Pacific (1) (Fig. 10C).

The new data presented here (Tab. 2), together with those previously reported in the scientific literature (Tab. 1), have allowed, for the first time, the compilation of a checklist of sea slugs in the Algerian coast. Overall, the list comprises 71 species belonging to 35 families and nine higher taxa (Tab. 3).

DISCUSSION

The faunal data collected in this study and from the published literature show that, to date, 71 species and 35 families of sea slugs have been recorded along the Algerian coast. Of these, the most representative are Nudibranchia (19 species, 11 families), Doridida (18, 6), Cephalaspidea (10, 8), Aplysiida (10, 1), and Sacoglossa (7, 3). Conversely, the least represented are Umbraculida (2, 2), Ringiculimorpha

(2, 1), Acteonoidea (1, 1), Pleurobranchida (1, 1), and Pteropoda (1, 1) (Fig. 10D).

The combined dataset highlights the distinctly Atlantic–Mediterranean character of this fauna. In fact, the data collected and presented in this study (Fig. 10C), both when examined separately and in combination with data from the literature, indicate a dominance of species with an Atlantic–Mediterranean chorotype (31 species) over those with other geographical distributions – Boreo-Atlantic (9), pan-oceanic (8), subtropical Atlantic (8), Mediterranean endemic (7), and Indo-Pacific (2) – which are clearly in the minority (Fig. 10E). This Atlantic–Mediterranean character of the fauna reflects the hydrodynamic conditions affecting the entire Algerian coast, which is characterised by a current of Atlantic origin (Millot & Taupier-Letage, 2005).

Examining the sea slug fauna of the Algerian coast, we observed several notable species, including *Ringicula buccinea* (Bakalem, 2008), *Anteaeolidiella lurana* (iNaturalist, 2024q; 2025l), Eolid sp. (iNaturalist, 2025q), *Marionia* cf. *gemmii* (2025g), *Felimida elegantula* (Koudri, pers. comm.), *Tayuva maculosa* (present study), *Martadoris mediterranea* (Fates, pers. comm.), *Retusa variabilis* (Bakalem, 2008), *Haminoea exigua* (iNaturalist, 2024s), *Roxania semilaevis* (Pruvot-Fol, 1954), *Aplysi*a sp. 2 (iNaturalist, 2025a; 2025d; 2025e; 2025g; Fates, pers. comm.), *Aplysia* sp. 3 (iNaturalist, 2024t), and *Dolabella auricularia* (Brahimi & Bensaou, 2018).

The Ringiculimorpha *R. buccinea* is considered a purely Atlantic species (Ciccone & Savona, 1982) and has been recorded only once in the Mediterranean Sea (Catalonia, Spain) (Cervera *et al.,* 2004). Of the three Nudibranchia species, one – the aeolidiid *A. lurana* – is a non-indigenous species in the Mediterranean Sea (Toso *et al.,* 2025) with an amphi-Atlantic distribution (Brazil, the Caribbean, Bermuda, the Canary Islands, Sardinia, Malta, Italy, Crete, and Australia) (Ballesteros *et al.,* 2025a); another – the Eolid sp. – is probably an undescribed species; and the third – *M.* cf. *gemmii* – is a Tritonina species recently described and currently known only from the Atlantic coasts of Galicia and Andalusia (Spain) and a few localities along the Mediterranean coasts of France and Italy (Almón *et al*., 2018; Trainito *et al*., 2021; Pontes *et al*., 2025a). *Felimida elegantula*, *T. maculosa*, and *M. mediterranea* are all considered rare Mediterranean endemic species: *F. elegantula* has been recorded in multiple locations along the Italian and French Mediterranean coasts, the Balearic Islands, Türkiye, and Tunisia (Lombardo & Marletta, 2023a); *Tayuva maculosa*, once common but growing increasingly difficult to encounter, is now considered rare (Lombardo & Marletta, 2023b); and *M. mediterranea* has been reported only from a few localities across the Mediterranean (Spain, Malta, Italy, and Greece) (Pontes *et al.,* 2025b). Also the three Cephalaspidea species reported here can be considered rare. For *H. exigua*, very few records of the living animal exist (Ballesteros *et al.,* 2025b), and *R. semilaevis* is also reported as rare (Arduino *et al.,* 2010), while the scant information on *R. variabilis* (Martynov & Korshunova, 2011; Kapeller, 2026) makes even the distribution of the species unclear (it may be endemic to the Black Sea) (Martynov & Korshunova, 2011). The two Aplysiida species here referred to as *Aplysia* sp. 2 and *Aplysia* sp. 3 are identical to the rare individuals reported by Lombardo and Marletta (in press) from the central-eastern coast of Sicily. Finally, the record of the Indo-Pacific and eastern Pacific aplysiid *D. auricularia* (Gosliner *et al*., 2018) seems to be the first for Mediterranean waters.

Nevertheless, when considering Algerian records of species documented in the literature (Tab.1), it is essential to bear in mind that the vast majority derive from studies that either do not illustrate the identified specimen(s) (Derbal & Kara, 2005; Bakalem, 2008; CAR/ASP-PLUE/PAM, 2015; Meziane *et al.,* 2020) or, when they do, show specimens that are severely contracted and preserved (Brahimi & Bensaou, 2018), or photographed out of water (Bensari *et al*., 2020) – both of which result in a considerable loss of external morphological characteristics. In essence, reports in Algerian literature that clearly depict sea slug species (Eleftheriou *et al.,* 2011; Tamsouri *et al.,* 2018) are the exception rather than the rule. This highlights the considerable importance of proper photography in documenting sea slug records along the Algerian coastline. Indeed, given the near absence of domestic specialists in this informal group of gastropod molluscs, the possibility of visually documenting the various specimens encountered would not only allow external experts to critically assess identifications, but also enable the photographic material to be re-examined at a later date. This would facilitate more accurate analyses and comparisons of the sea slug faunas across different areas of the Algerian coast.

Clearly, visual documentation of species cannot always be flawless, as some species are cryptic, and there is always the possibility of discovering taxa that are still unknown and therefore undescribed. In such cases, detailed morphological and genetic analyses are essential. Otherwise, the use of photography to document sea slug faunas remains best practice and an excellent starting point in a region lacking domestic specialists in the field.

Algerian enthusiasts of marine organisms have indeed shown remarkable foresight, photographing the various species of sea slugs along the coastal areas considered herein (Tab. 2 and References). Nevertheless, their documentation effort has presented significant gaps, related mainly to the lack of systematic sampling of animals and the focus on only certain areas. The first gap is readily apparent in the complete absence of data beyond simple photographic documentation for the species and areas in question (*e.g.*, information on seasonality, abundance, bathymetric and thermal ranges, reproductive periods, behavioural observations, etc.). The second gap is evident from the graph in Figure 10B, which shows that – at least as far as the new data presented in this study are concerned – the documentation of these animals has focused almost exclusively on three wilayas: Jijel (31 species, 14 families), Oran (20, 9), and Algiers (14, 10), while leaving others virtually unexplored, namely: Tlemcen (3, 3), Tipaza (3, 3), Tizi Ouzou (4, 3), Boumerdès (3, 2), Aïn Témouchent (1, 1), Mostaganem (1, 1), and Skikda (1, 1).

In light of the issues above, as well as the near-total lack of specialist studies on the sea slugs of the Algerian coast, and the richness of its marine environment, current data on this faunal group in the area are likely greatly underestimated.

CONCLUSIONS

In summary, the study of sea slugs in Algeria has never been particularly successful. This situation, mainly due to the lack of local experts on this faunal group, has led, on the one hand, to a considerable knowledge gap (pointed to by the present study) and, on the other hand, to a fragmentation of the little information available (Dieuzeide, 1951; Pruvot-Fol, 1954; Derbal & Kara, 2005; Bakalem, 2008; Camacho-García & Gosliner, 2008; Refes *et al.*, 2010; Eleftheriou *et al.*, 2011; CAR/ASP-PLUE/PAM, 2015; Brahimi & Bensaou, 2018; Tamsouri *et al.*, 2018; Bensari *et al.*, 2020; Meziane *et al.*, 2020).

In almost all cases, this information goes no further than simple records of single species. Consequently, qualitative data on Algerian sea slug faunas remain very scarce, while quantitative are practically non-existent. Given the considerable richness of the Algerian marine environment, its geographical position in the Mediterranean, and the ongoing loss of biodiversity (CAR/ASP-PLUE/PAM, 2015; MEER & SPA/RAC-ONU Environment/PAM, 2018), this situation should be addressed as soon as possible through the collection of new data on these animals. Over time, such studies will help fill the knowledge gap on this wonderful and mysterious group of molluscs.

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PRVI PRISPEVEK K PROUČEVANJU FAVNE „GOLIH MORSKIH POLŽEV" (GASTROPODA, HETEROBRANCHIA) ALŽIRSKE OBALE

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POVZETEK

V Alžiriji so se raziskave o neformalno definirani skupini „golih morskih polžev" doslej osredotočale izključno na sporadične najdbe vrst z različnih območij lokalne obale. Zaradi tega ostaja favna golih morskih polžev alžirske obale v veliki meri nepoznana. Namen te raziskave je bil pripraviti prvi seznam golih morskih polžev alžirske obale s pregledom novih fotografskih in terenskih podatkov, zbranih med letoma 2010 in 2025. Na podlagi teh novih podatkov in objavljene literature je bilo mogoče potrditi, da je bilo v regiji do danes zabeleženih 71 vrst golih morskih polžev, ki pripadajo 35 družinam. Glede na zgodovinsko pomanjkanje strokovnjakov za to favnistično skupino v Alžiriji in visoko raznolikost morskega okolja njene obale, je to število verjetno precej podcenjeno.

Ključne besede: Alžirija, popis vrst, ljubiteljska znanost, goli morski polži, Heterobranchia, morski zaškrgarji

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iNaturalist (2025e): 268141732 (https://www.inaturalist.org/observations/268141732).

iNaturalist (2025f): 268141731 (https://www.inaturalist.org/observations/268141731).

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ASSESSING SOFT-BOTTOM EPIBENTHIC COMMUNITIES: METHODOLOGICAL INSIGHTS INTO DREDGING AND VIDEO SURVEYS

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ABSTRACT

The study compared two approaches, sampling using a dredge and non-invasive video surveys using a camera dredge and a video sledge, for assessing soft-bottom epibenthic communities. Sampling was conducted over a detritic muddy-sandy bottom. Altogether171 taxa were identified, with only a small subset shared among all methods. Dredging yielded the highest number of taxa, particularly small, cryptic and sediment-associated, and provided biomass data. Conversely, video-based methods detected a lower number of taxa yet could detect more vagile species and could quantify some species like sponges. Video sledge surveys provided the most extensive coverage and the highest number of habitat and community parameters. The findings indicate that dredge and video-based methodologies yield complementary ecological insights, indicating that a combination of methods should be employed for the more comprehensive monitoring and assessment.

Key words: epibenthos, soft-bottom circalittoral, dredge sampling, camera dredge, video sledge, Adriatic Sea-

VALUTAZIONE DELLE COMUNITÀ EPIBENTONICHE DEI FONDALI A SUBSTRATO MOLLE: CONSIDERAZIONI METODOLOGICHE SULLE CAMPAGNE DI CAMPIONAMENTO CON DRAGA E SULLE INDAGINI VIDEO

SINTESI

Lo studio ha confrontato il campionamento con draga e le indagini video non invasive (draga con telecamera e slitta video) per la valutazione delle comunità epibentoniche dei fondali molli. I campionamenti, effettuati su un fondale detritico fangoso-sabbioso, hanno permesso di identificare 171 taxa, con una limitata sovrapposizione tra i metodi. La draga ha rilevato il maggior numero di taxa, soprattutto specie piccole, criptiche e associate al sedimento, fornendo anche dati sulla biomassa. I metodi video hanno identificato meno taxa, ma si sono dimostrati più efficaci nel rilevare specie vagili e nel quantificare organismi importanti come le spugne. La slitta video ha inoltre garantito la maggiore copertura e la raccolta del maggior numero di informazioni su habitat e comunità. I risultati evidenziano la complementarità tra i metodi di campionamento, suggerendo l'impiego integrato di draga e tecniche video per un monitoraggio più completo degli ecosistemi bentonici.

Parole chiave: epibenthos, fondali molli circalitorali, campionamento con draga, draga con telecamera, slitta video, Adriatico

INTRODUCTION

Soft-bottom benthic habitats are among the most widespread marine environments and support diverse epibenthic assemblages composed of organisms such as sponges, molluscs, crustaceans, tunicates, echinoderms and various other mobile or sessile taxa. These communities contribute to ecosystem functioning through their roles in trophic interactions, sediment–organism relationships and habitat structuring. Their composition and spatial organisation are influenced by sediment characteristics, hydrodynamic conditions and environmental gradients, and therefore reflect both natural variability and anthropogenic disturbance (Jones, 1950; Fedra *et al.*, 1976; Eleftheriou & Moore, 2005).

In the northern Adriatic Sea, and particularly in the Gulf of Trieste, benthic communities have long been recognised as spatially heterogeneous and strongly shaped by local environmental conditions. Earlier studies described the structure and distribution of North Adriatic benthic communities (Gamulin-Brida, 1974; Fedra *et al.,* 1976), while more recent regional research has confirmed the ecological importance and variability of soft-bottom assemblages in the southern part of the Gulf of Trieste (Mavrič *et al.*, 2010). Sediment diversity and environmental gradients in this area further contribute to the complexity of benthic habitats, making reliable assessment methods particularly important for regional monitoring and management (Orlando-Bonaca *et al.,* 2012; Čermelj *et al.,* 2019).

Assessment of epibenthic communities has traditionally relied on direct sampling methods, including dredging and trawling. Such methods provide physical specimens and therefore allow detailed taxonomic identification, abundance estimates and, in some cases, biomass assessment. They are especially valuable for detecting small, cryptic and sediment-associated taxa that are difficult to identify visually (McIntyre, 1956; Eleftheriou & Moore, 2005). However, dredge-based sampling is invasive, spatially limited and affected by gear selectivity. Physical disturbance of the seabed, selective retention of organisms and possible fragmentation or loss of fragile taxa may influence the composition of the collected sample and consequently affect ecological interpretation (Hall & Harding, 1997; Kaiser *et al.*, 2000; Lindegarth *et al.*, 2000).

Non-destructive visual techniques, including towed video systems and video sledges, have increasingly been used to complement traditional sampling (Service & Golding, 2001). These approaches enable *in situ* observation of epibenthic organisms and provide information on habitat morphology, spatial distribution patterns and ecological context over larger areas than direct sampling methods. They are particularly useful for documenting larger, conspicuous, sessile and habitat-forming organisms, as well as features that are difficult to preserve in physical samples (Service & Golding, 2001; Jørgensen *et al.*, 2011; Flannery & Przeslawski, 2015). Nevertheless, video-based methods are constrained by image quality, visibility conditions and observer expertise, and usually have lower taxonomic resolution for small, cryptic or sediment-associated organisms (Service & Golding, 2001; Ierodiaconou *et al.,* 2011; Flannery & Przeslawski, 2015).

Because each sampling method favours different components of the epibenthic community, methodological bias represents a central issue in benthic biodiversity assessment. Direct sampling may better detect small and sediment-associated organisms, whereas visual methods more effectively capture larger, conspicuous and structure-forming taxa. As a result, different methods may produce different estimates of taxonomic richness, dominance structure, abundance and habitat relevance. This methodological selectivity has been recognised since early comparisons of benthic sampling techniques and remains an important consideration in modern survey design (McIntyre, 1956; Uzmann *et al.*, 1977; Bowden & Hewitt, 2012).

The integration of destructive and non-destructive approaches therefore offers a promising way to improve the completeness and reliability of epibenthic community assessments. Previous studies have shown that combining different sampling approaches can reduce uncertainty and provide a more comprehensive understanding of benthic community structure than any single method alone (Solan *et al.*, 2003; Jørgensen *et al.*, 2011; Bowden & Hewitt, 2012).

Despite these advantages, applications of video-based surveys of benthic habitats and communities, but even more comparative evaluations of physical sampling and video-based surveys remain limited, particularly for soft-bottom habitats of the northern Adriatic Sea. This kind of research is important because methodological choice can directly influence conclusions about biodiversity, dominant taxa, habitat structure and the ecological status of benthic communities and results of such studies can help us in improving new surveys and status assessments of benthic habitat types and communities and in interpreting and re-evaluating historical data mainly coming from physical sampling.

Due to this and in the scope of monitoring and assessment needs following the Marine Strategy Framework Directive and Nature Restoration Law, the present study is focusing on the comparison of two distinct sampling approaches—dredge sampling and video-based surveys (using camera-on-dredge observations and video sledge surveys)—in the epibenthic-rich soft-bottom of the Gulf of Trieste. The objectives were: (i) to compare the taxonomic composition and community information obtained by each method; (ii) to identify method-specific biases related to organism detectability, quantification and taxonomic resolution; and (iii) to evaluate the complementarity of these approaches for benthic monitoring and ecological assessment.

MATERIAL AND METHODS

Study area

The study was conducted in the Gulf of Trieste, a semi-enclosed, shallow basin with an average depth of 20 m (Trobec *et al.*, 2018). It is characterised by pronounced environmental gradients and strong seasonal variability in temperature and salinity, all being influenced by riverine inputs, atmospheric forcing, hydrodynamic processes and high levels of anthropogenic pressures (Boicurt *et al.*, 1999; Malačič & Petelin, 2001; Malačič *et al.*, 2006; Tondelli *et al.,* 2025). Water temperature analyses over the period 2001–2022 reveal that monthly mean minima occur in February (8.93 ± 0.03 °C) and maxima in August (23.56 ± 0.05 °C) and strong intra-annual variability and confirm a significant long-term warming trend of about 0.06 °C per year (Tondelli *et al.,* 2025). Salinity typically ranges between 25 and 38 PSU, with an average value of 35 PSU being among the lowest in the Mediterranean (Boicourt *et al.*, 1999; Cozzi *et al.*, 2012). River dischargers are also responsible for high nutrient and sediment supply into the Gulf and together with insolation, evaporation and periodic strong winds (bora and sirocco) affect water stratification, which contributes also to occasional events of anoxia and hypoxia (Malačič *et al.*, 2006; Zuschin & Stachowitsch, 2009).

The sampling was conducted in the south-western part of the Gulf of Trieste (northern Adriatic Sea), on the shallow circalittoral muddy-sands containing up to 30 % of pelite fraction and 45 % of biogenic detritus (Mavrič *et al.*, 2023). The bottoms are dominated by the epibenthic community of coastal detritic bottoms that transitions into the community of muddy detritic bottoms (Fedra *et al.*, 1976; Mavrič *et al.*, 2023).

Sampling design and sample processing

To evaluate methodological performance for habitat and epibenthic community assessment, three sampling approaches were applied: (i) dredge sampling, (ii) video observations using a camera mounted on the dredge (camera dredge) and (iii) video sledge surveys. Sampling was conducted on 15 stations

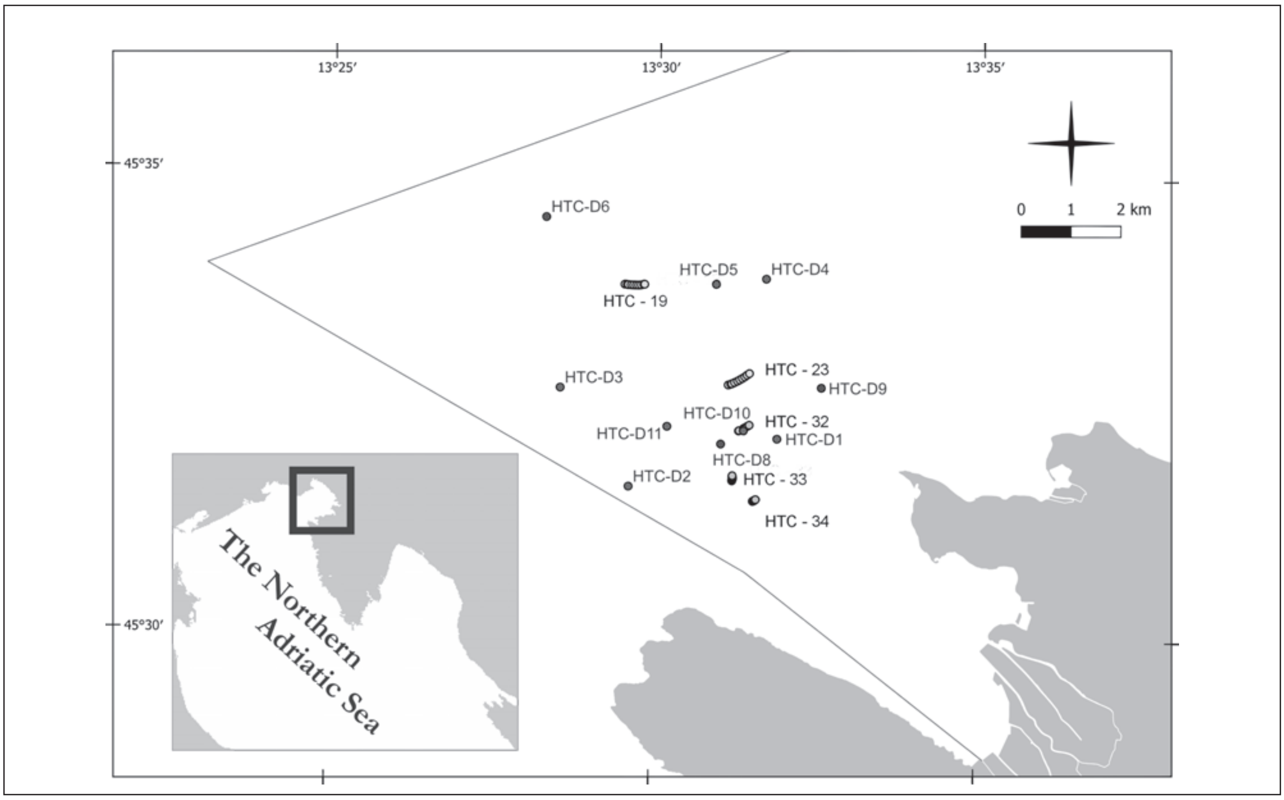

Fig. 1: Map of the areas sampled and surveyed using the dredge (labels HTC-D) and video sledge (HTC-).
Sl. 1: Zemljevid vzorčevalnih območij, pregledanih z dredžo (oznake HTC-D) in video sani (HTC-).

Tab. 1: List of transects where data for the research were collected.
Tab. 1: Seznam transektov, na katerih so bili zbrani podatki za raziskavo.

Name of the Survey	Date	Start of sampling		End of sampling		Depth (m)	Transect duration (mm:ss)	Transect lenght (m)	Speed (knots)
		LAT (N)	LON (E)	LAT (N)	LON (E)				
HTC-D1	16.02.2022	45°32.166'	13°31.804'	45°32.235'	13°31.653'	22	04:00	144	0.9
HTC-D2	22.02.2022	45°31.633'	13°29.544'	45°31.385'	13°29.465'	22	01:30	49	0.65
HTC-D3	22.02.2022	45°32.683'	13°28.477'	45°32.631'	13°28.491'	22	03:00	80	0.8
HTC-D4	9.03.2022	45°33.883'	13°31.601'	45°33.921'	13°31.619'	23	03:00	71	0.7
HTC-D5	10.03.2022	45°33.818'	13°30.837'	45°33.823'	13°30.900'	23	03:30	74	0.7
HTC-D6	14.03.2022	45°34.512'	13°28.222'	45°34.444'	13°28.178'	22	03:00	95	0.9
HTC-D8	16.03.2022	45°32.103'	13°30.945'	45°32.151'	13°30.955'	22	01:30	48	0.9
HTC-D9	21.03.2022	45°32.722'	13°32.469'	45°32.702'	13°32.419'	22	02:00	64	0.8
HTC-D10	22.03.2022	45°32.249'	13°31.289'	45°32.223'	13°31.241'	21	01:00	33	0.8
HTC-D11	22.03.2022	45°32.283'	13°30.119'	45°32.273'	13°30.059'	23	02:00	55	0.8
HTC - 19	23.03.2022	45°33.796′	13°29.508′	45°33.799′	13°29.812′	22	19:35	453	0.6
HTC - 23	24.03.2022	45°32.724′	13°31.129′	45°32.851′	13°31.453′	21	19:08	439	0.6
HTC - 32	25.03.2022	45°32.228′	13°31.300′	45°32.291′	13°31.462′	21	15:06	257	0.5
HTC - 33	28.03.2022	45°31.686′	13°31.209′	45°31.741′	13°31.214′	21	10:30	77	0.3
HTC - 34	28.03.2022	45°31.467′	13°31.533′	45°31.486′	13°31.579′	20	08:40	76	0.2

located within the circalittoral zone, with depths ranging from 20 to 25 m, where the bottom is comprised of detritic muddy-sandy sediments. Dredging and video observations using a camera mounted on the dredge were performed simultaneously on 10 transects, while video sledge surveys were performed on 5 transects adjacent to the first ones (Fig. 1, Tab. 1). All sampling approaches were conducted in the period between 16.02.2022 and 28.03.2022 (Tab. 1), to assure comparable environmental conditions. The choice of period was mainly dictated by water clarity conditions, which are usually the best between February and the beginning of April.

Dredging and camera dredging were performed using a scientific dredge with a net with openings of 20 x 23 mm, attached to a 60 cm wide metal frame (Fig. 2). On the top of the metal frame a video recording set-up was mounted, composed of a GoPro HERO 9 camera, a laser scale (two laser beams set 10 cm apart) and two video lights. This video system provided close-range observations of benthic organisms and substrate conditions along the dredge path. For each dredging, transect start and end GPS coordinates were taken, together with data on depth, time and speed of dredging. Dredging was performed for 1 to 4 minutes using the relatively constant speed

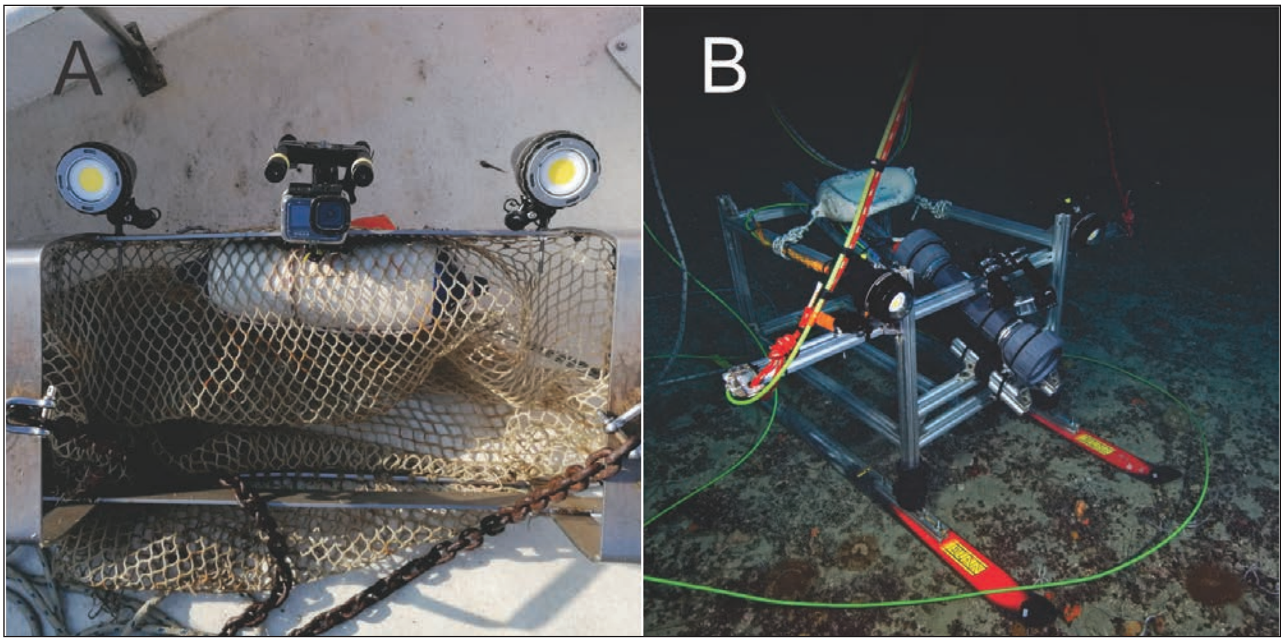

Fig. 2: Sampling devices used in the study; A – a scientific dredge, additionally equipped with a GoPro Hero camera, a laser scale and video lights, B – a video sledge equipped with three cameras, a laser scale and video lights (photo: B. Mavrič).

Sl. 2: Vzorčevalne naprave, uporabljene v raziskavi; A – znanstvena dredža, dodatno opremljena s kamero GoPro Hero, laserskim merilom in video lučmi, B – video sani, opremljene s tremi kamerami, laserskim merilom in video lučmi (foto: B. Mavrič).

between 0.65 and 0.9 knots, resulting in the length of transects between 33 and 144 meters (Tab. 1). Physical samples were transferred from the dredge into separate tanks with water for further processing on land, while video recordings were transferred from cameras to a computer for later analyses.

Video sledge system was equipped with three separate cameras, two main recording cameras (GoPro Hero 9), set at different angles and distances from the bottom to enable different views on the same positions and one IP control camera, connected with the cable to the boat above, enabling real time control of the situation underwater and survey performance. Besides the cameras the video system was complemented with one laser scale (two laser beams set 10 cm apart) and two video lights. For each survey, start, end and intermittent GPS coordinates (approximately every three minutes) were taken along the transect, together with data on depth, time and speed of survey. Active surveys lasted from around 12 to 24 minutes, with active sliding time between 9 and 20 minutes, with the speed between 0.3 and 0.6 knots, resulting in the length of the whole surveyed transects between 77 and 453 meters (Tab. 1). After the survey video recordings were transferred from cameras to a computer for later analyses.

Material collected with the dredge was firstly separated into broader taxonomical groups and weighted to the nearest g. Than specimens were determined to the lowest possible taxonomic level and counted if possible. For some taxa biometry data were measured, together with some other observations like sex, symbiotic relationships, etc.

Video material was checked on the computer. Camera dredge video transects were analysed as whole, while videos from the video sledge were separated into subtransects of around 3 min length (to match approximately the dredged transects in the area covered) and then analysed separately. Observed organisms were determined to the lowest possible taxon and counted. Besides this, other data were annotated like specimen size, behaviour and other biotic relationships (*e.g.*, presence of clumps, symbiosis), habitat appearance, bottom structure, organism distribution, etc.

Statistical analysis

Statistical analyses were performed to compare the ecological information obtained by dredge sampling, camera-on-dredge observations and video sledge surveys. Taxonomic composition was summarised as the total number of recorded taxa, the number of taxa identified to species level and the number of quantifiable taxa for each method. Mutual and method-specific taxa were visualised using a Venn diagram to assess methodological overlap and complementarity. Taxa richness was calculated as the number of quantifiable taxa per sampling unit, while abundance data were standardised as density, expressed as individuals per 100 m^2. For video sledge surveys, analyses were performed both for whole transects and shorter subtransects to allow comparison with the smaller spatial extent covered by dredging.

Differences in taxa richness and total density among methods were tested using Kruskal–Wallis tests, followed by Dunn's post hoc tests when appropriate. Paired Wilcoxon tests were used for direct comparisons between dredge and camera-on-dredge data collected along the same transects. Frequency of occurrence was calculated for each taxon and visualised using shade plots. Dominant taxa were identified according to mean relative density. Community composition was analysed using square-root-transformed density data, Bray–Curtis dissimilarities, nMDS ordination and PERMANOVA, with PERMDISP used to assess homogeneity of dispersion. Method performance was additionally evaluated descriptively using predefined ecological and practical criteria.

RESULTS

Application of all three methods resulted in a list of parameters we could obtain by each of them and is presented in the Table 2. Using the dredge we could assess 5 parameters, using the camera dredge 7 and with the video sledge 8 parameters out of 9 altogether. The only parameter we could assess solely with the dredge was biomass, while the video-based methods gave us insights into habitat appearances underwater, like seabed morphology, distribution patterns on the seabed, bahaviour of the organisms and their interactions, and assessment of clumps of organisms. The only three parameters we could assess with all three methods were taxonomic composition and abundance/density of organism. For this reason, we took a closer look at the performance of the three methods in assessing these three parameters.

Tab. 2: List of parameters we could assess with the three methods.

Tab. 2: Seznam parametrov, ki smo jih lahko ocenili s tremi metodami.

Parameters	Dredge	Camera dredge	Video sledge
biomass	+	-	-
taxonomic composition	+	+	+
abundance/density	+	+	+
frequency of occurence	+	+	+
ind. size measurements	+	-	+
clumps analyses	-	+	+
species behaviour/ interactions	-	+	+
bottom morphological features	-	+	+
distribution patterns	-	+	+

A total of 171 mainly animal taxa were recorded across all sampling methods. Results on taxonomic composition obtained by all three methods clearly reflect differences in detection capabilities among methods. Dredge sampling recorded the highest number of taxa (129) with 104 determined to the species level. Video-based approaches recorded fewer taxa overall, the camera dredge 52 taxa out of them 39 determined to the species level and the video sledge 106 taxa with 77 species. Thirty-nine taxa were obtained by all three methods, 25 were obtained by both the dredge and the video sledge method, 8 by the camera dredge and the video sledge and 5 by the dredge and the camera dredge method. Sixty taxa were obtained solely by the dredge and 34 by the video sledge, while with the camera dredge, we obtained no exclusive taxa (Fig. 3).

The number of taxa we could quantify (density per 100 m^2) were slightly lower than the number of taxa we could determine. The majority of taxa we could not count were obtained by dredging (42), while only one taxon from video-based methods was not quantifiable, namely algae *Peyssonnelia squamaria*. The highest number of countable taxa per one sampling was obtained with the video sledge over a whole length transect (55 on average) covering far more sea bottom than with the other two methods. By splitting the transect of video sledge into smaller sub-transects covering a similar area than other two methods, the number of obtained taxa per sample dropped to 33 on average which is higher than the number of taxa obtained with the camera dredge (28) and lower than 39 recorded with the dredge (Fig. 4).

Most taxa obtained by dredging belonged to molluscs (29), followed closely by poriferans (28), crustaceans (21), tunicates (15), bryozoans (12) and echinoderms (11) (Fig. 5). The most taxa-richest group obtained by both video based approaches were poriferans (17 with camera dredge and 25 with video sledge), which were in camera dredge method followed by tunicates (10), molluscs (9) echinoderms (8) and cnidar-

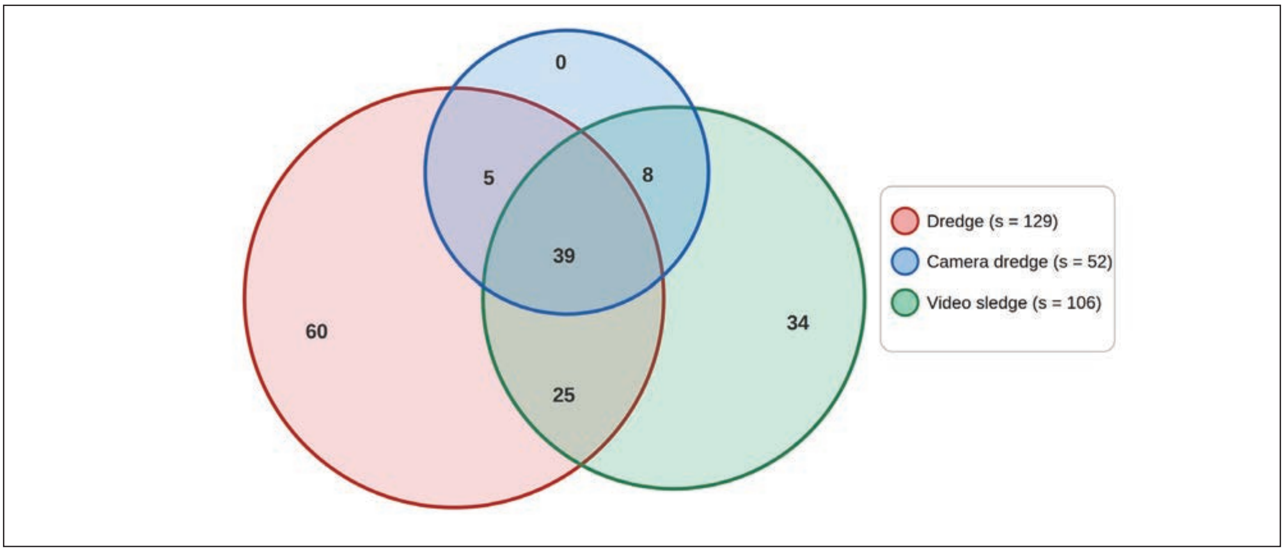

Fig. 3: Venn diagram presenting the number of taxa obtained by three methods (three differently coloured circles), split into categories based on the fact if taxa were obtained exclusively with one method (number in an area covered by only one circle), with two out of three (area covered by two circles or by all three methods (number in an area covered by all three circles).

Sl. 3: Vennov diagram prikazuje število taksonov, ugotovljenih s tremi metodami (trije različno obarvani krogi), razdeljenih v kategorije glede na to, ali so bili taksoni ugotovljeni izključno z eno metodo (število v območju, ki ga pokriva le en krog), z dvema od treh (območje, ki ga pokrivata dva kroga) ali z vsemi tremi metodami (število v območju, ki ga pokrivajo vsi trije krogi).

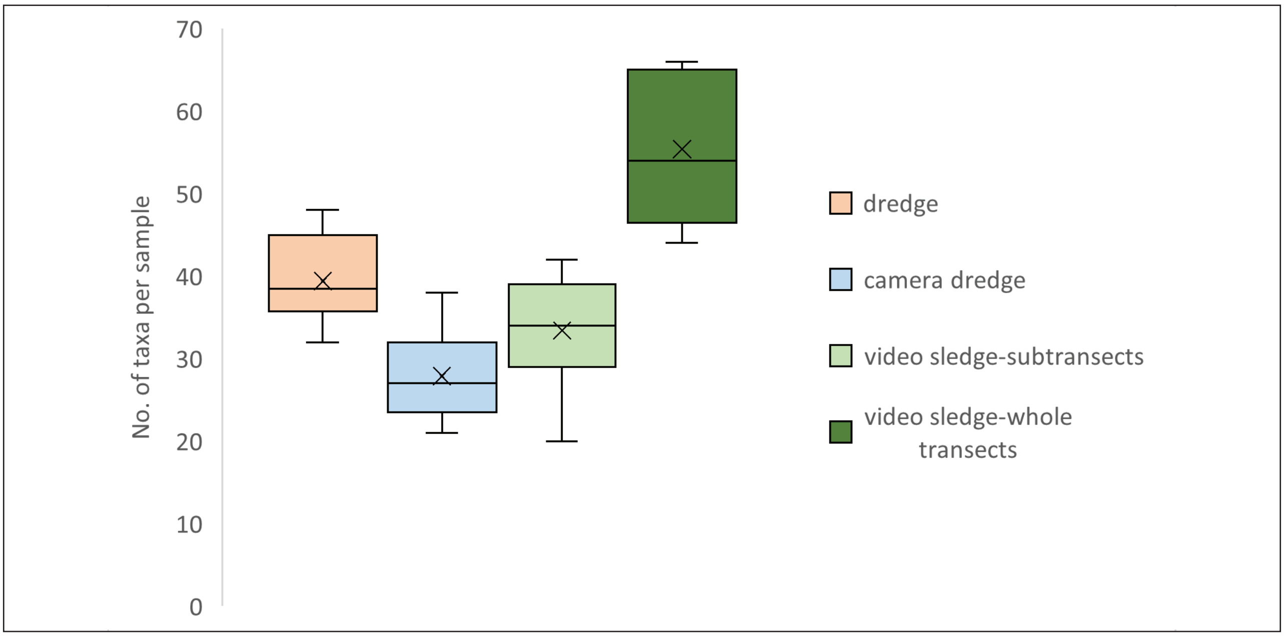

Fig. 4: The number of taxa per sample (only those for which abundance data could be obtained) presented with a box whiskers plot for method. For the video sledge two box plots were drawn, one with data obtained per subtransects and the other per whole transects recorded on one site.

Sl. 4: Število taksonov na vzorec (le tisti, za katere so bili pridobljeni podatki o abundanci) je prikazano z grafikonom kvantilov glede na metodo vzorčenja. Za video sani sta bila izrisana dva diagrama: eden s podatki, pridobljenimi na raven subtransektov, in drugi na raven celotnih transektov, posnetih na posamezni lokaciji.

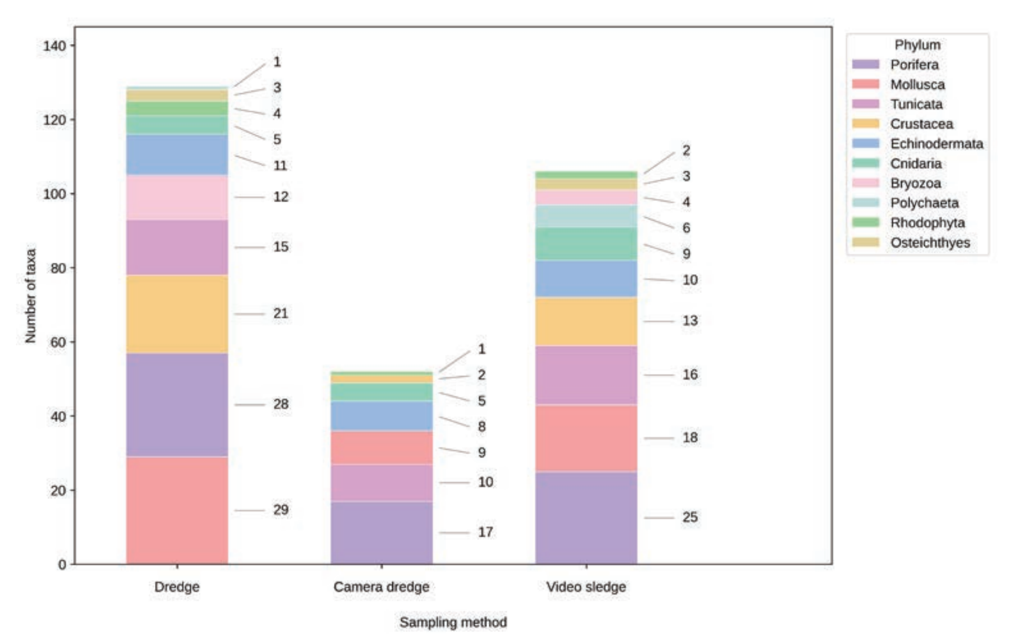

Fig. 5: The number of taxa per higher taxonomic category for each sampling method.
Sl. 5: Število taksonov na višjo taksonomsko kategorijo za vsako metodo vzorčenja.

ians (5) and in video sledge method by molluscs (18), tunicates (16), crustaceans (13), echinoderms (10) and cnidarians (9). According to this, the dredge and the video sledge sampling are more resembling. With the dredge we obtained a far higher number of mollusc, crustacean and bryozoan taxa, while with the video sledge significantly more cnidarian and polychaete taxa were recorded (Fig. 5).

Observations undertaken with the camera affixed to the dredge yielded additional information by virtue of the fact that they enabled the capture of organisms in direct proximity to the dredge's trajectory. This method often recorded taxa that were either disturbed or only partially retained during dredging, including mobile crustaceans and larger epifaunal organisms. Furthermore, it facilitated the acquisition of supplementary observations pertaining to substrate-associated fauna, which exhibited a lack of consistency in their preservation within dredge samples.

Looking at the data of frequency of occurrence, it is even more evident that not all taxa are equally detectable with all three methods (Fig. 6). There are some taxa with high frequency of occurrence obtained using video-based methods, especially video sledge, like anemone *Phymanthus pulcher,* that were never detected in dredge samples. On the other hand, there are even more examples of the taxa that were recorded in dredge samples, but hardly or not with video-based methods, especially small crab species like *Pisidia bluteli, Pilumnus spinifer* and *Ethusa mascarone*.

No statistically significant differences in recorded densities of all organisms per sample were obtained between sampling methods, although the increasing trend is evident from the camera dredge with the lowest average value (4334 ind/m^2), followed by the dredge (4733 ind/m^2) and the video sledge (6233 ind/m^2) (Fig. 7).

Analyses of the average densities of the individual taxa per sampling method revealed that in all three methods the far most dominant taxon was a brittlestar species *Ophiothrix quinquemaculata* (Fig. 8)*,* whose relative densities were with all methods higher than 70%. With the dredge the second most dominant organism turned out to be a sea urchin *Psammechinus microtuberculatus*, followed closely by a clam *Mimachlamys varia* and by a crustacean *Paguristes eremita*. *P. microtuberculatus* was not among the 9 most dominant taxa obtained by the video sledge and it came 7th with the camera dredge. In both video-based methods the second most abundant taxon was anemone *Cereus pedunculatus*, which was only the 9th most abundant taxon in dredge samples. The third most dominant taxon with the video sledge was a sponge *Ulosa stuposa,* which came fourth with the camera sledge and could not be counted in dredge samples due to its fragmentation. The same is true also for a sponge *Mycale tunicata* which was absent from the density data from the dredge but was amongst the most abundant taxa in video-based methods. Both rounded and robust sponge species *Tethya citrina* and *Suberites domuncula* were among

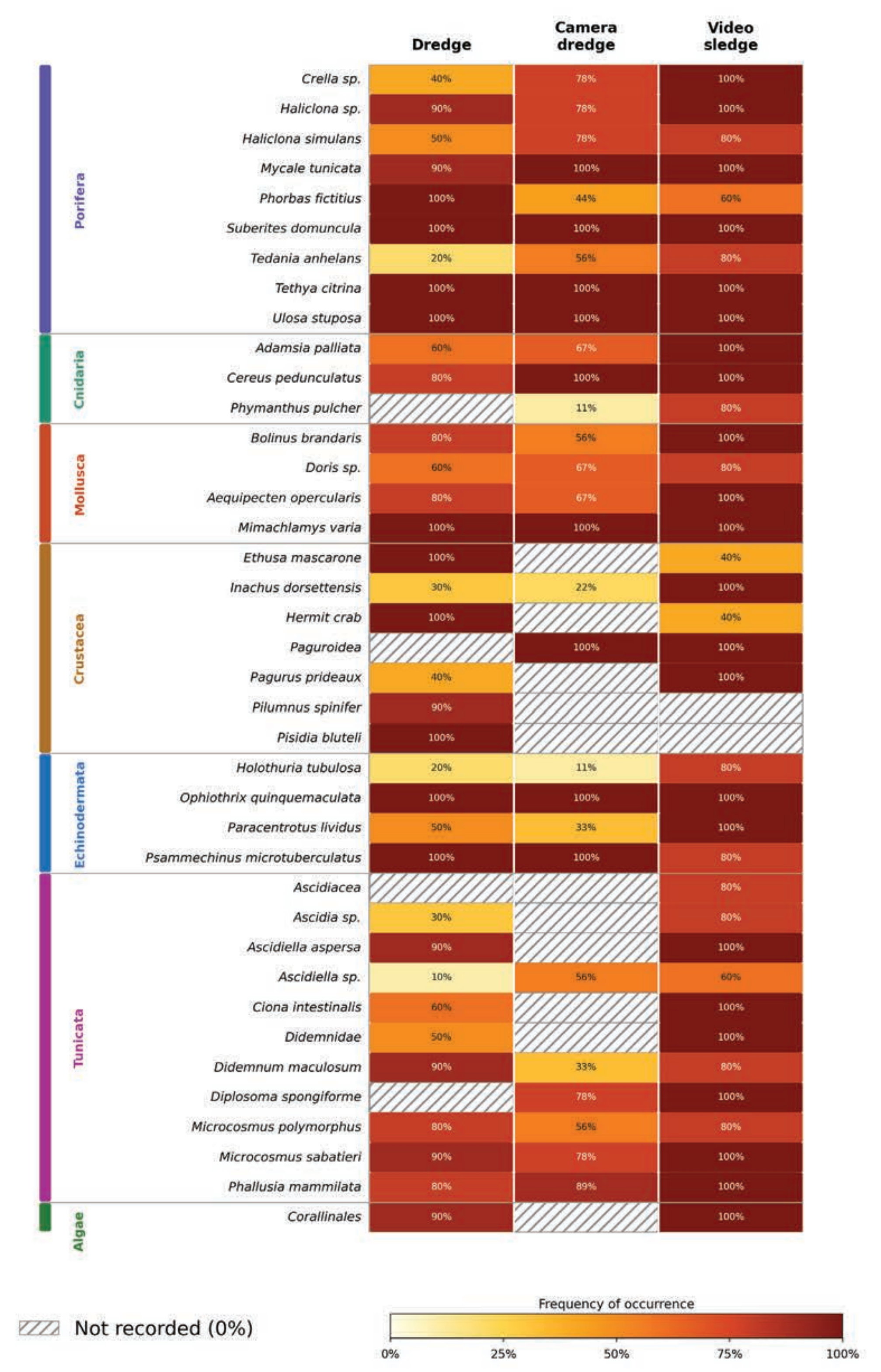

Fig. 6: A shade diagram with a frequency of occurrence of selected taxa whose occurrence was >80% in at least one of the sampling methods.

Sl. 6: Senčni diagram s frekvenco pojavljanja izbranih taksonov, katerih pojavnost je bila večja od 80 % v vsaj eni od metod vzorčenja.

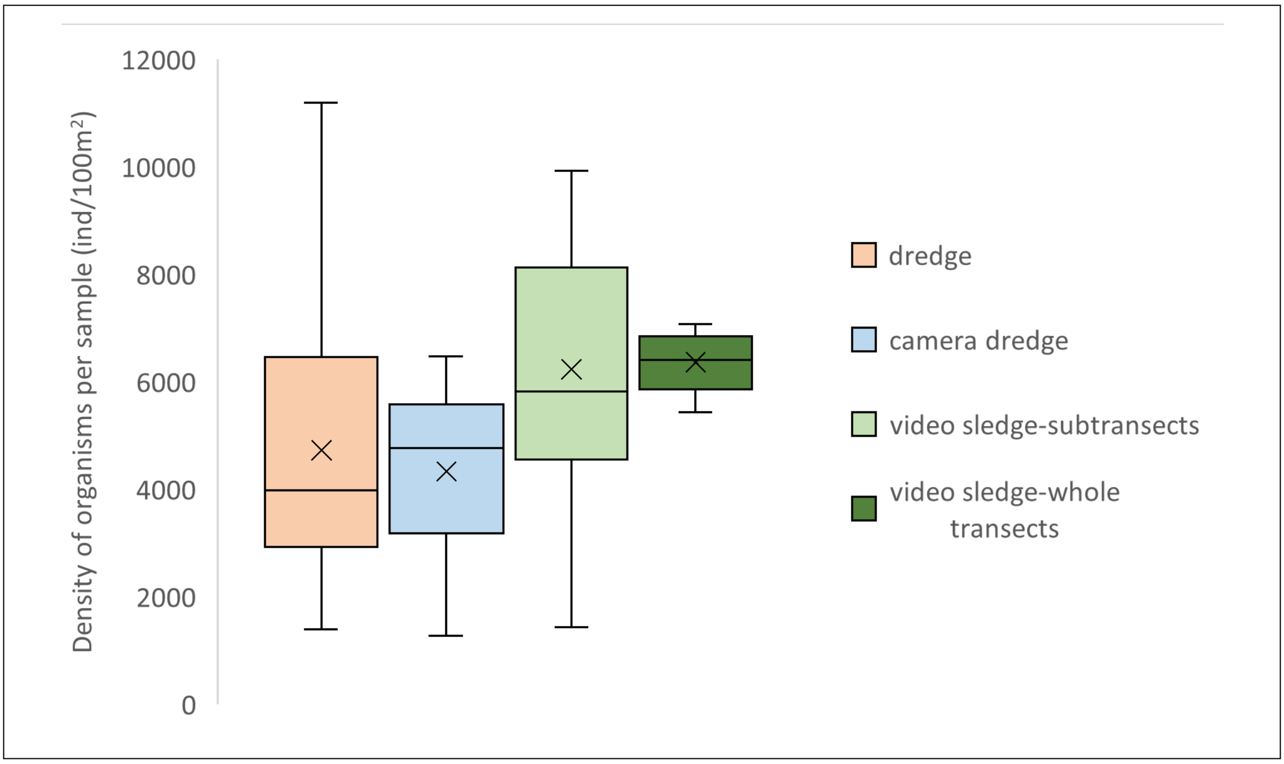

Fig. 7: Densities of organisms (ind./100m²) per sample presented with a box whiskers plot for each of the three methods. For the video sledge two box plots were drawn, one with data obtained per subtransects and the other per whole transects recorded on one site.

Sl. 7: Gostote organizmov (osebkov/100 m²) na vzorec, prikazane z grafikoni kvantilov za vsako od treh metod. Za video sani sta bila izrisana dva grafikona kvantilov, eden s podatki, pridobljenimi na podtransektih, in drugi po podatkih na celotnih transektih, posnetih na enem mestu.

the most dominant species in all three methods. There are two species recorded amongst the most abundant in dredge samples, *Paguristes eremita* and *Pisidia bluteli*, that are not among the most abundant species obtained by video-based methods. Specimens of *P. eremita* are in video-based methods mostly determined as taxon Paguroidea, which is listed amongst the most abundant taxa obtained with both methods. *Pisidia bluteli* on the other hand is a small anomuran that was not at all recorded with video-based methods.

Overall performance of the three methods was assessed based on several criteria presented in the Table 3. The video sledge turned out as the most appropriate method, especially due to its non-destructiveness, highest sampling and analyses efficiency, applicability in a broader range of soft-bottom habitats and highest number of habitat/community parameters that could be assessed. The only drawback in comparison to the dredge sampling were taxa detection and taxonomic precision and reliability, especially with smaller organisms and in cases of lower visibility, which affected video quality.

DISCUSSION

The comparison of three methods proves that dredge sampling, and video-based surveys provide substantially different yet complementary perspectives on soft-bottom epibenthic communities. Dredge sampling yielded the highest number of detected taxa, whereas video-based approaches recorded fewer taxa but provided important insights into spatial patterns and ecological context. These differences reflect inherent methodological biases related to gear selectivity and organism detectability, which have long been recognised in benthic sampling studies (McIntyre, 1956; Uzmann *et al.*, 1977).

Dredge sampling proved particularly effective in detecting small, cryptic, and sediment-associated taxa, including numerous molluscs and crustaceans. This finding is consistent with previous studies highlighting the high taxonomic resolution of destructive sampling methods (Kaiser *et al.*, 2000; Eleftheriou & Moore, 2005). However, the invasive nature of dredging, combined with its limited spatial coverage, constrains its ability to represent habitat heterogeneity and broader community structure. Furthermore, physical disturbance caused by the continuous gear usage may alter benthic assemblages and influence sample composition (Hall & Harding, 1997; Lindegarth *et al.*, 2000).

In contrast, video-based methods showed a clear tendency to detect larger, sessile, and structure-forming taxa, such as sponges and other conspicuous epibenthic organisms. These taxa are often underrepresented in dredge samples due to fragmentation, escape, or loss during sampling. Similar patterns have been reported in visual survey studies, where conspicuous organisms dominate observations (Jorgenson *et al.*, 2011; Flannery & Przeslawski, 2015). In addition, video approaches significantly improve spatial coverage and allow *in situ* assessment of habitat structure and organism interactions. However, they are inherently limited

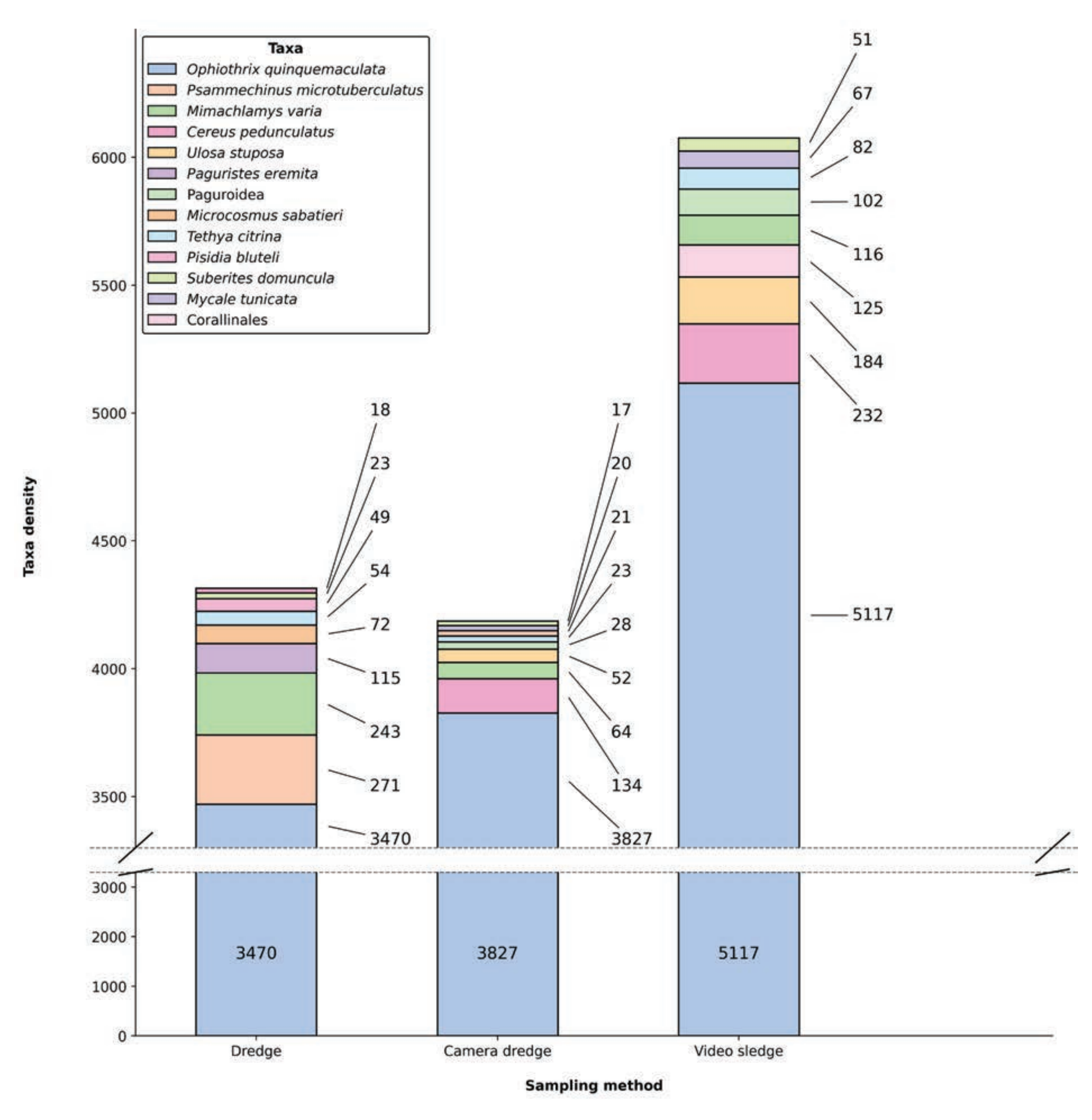

Fig. 8: Densities of individuals (ind./100m²) of the first 9 most abundant taxa for each sampling method.
Sl. 8: Gostote osebkov (osebkov/100 m²) prvih 9 najpogostejših taksonov za vsako metodo vzorčenja.

Tab. 3: Overall assessment of the performance of the three methods.
Tab. 3: Splošna ocena uspešnosti treh metod.

Criteria	**Dredge**	**Camera dredge**	**Video sledge**
Environmental suitability	destructive	semi-destructive	non-destructive
habitat applicability	mobile sedimentary bottoms with a low amount of pelite fraction (<30%); limited use in vulnerable and protected habitats	mobile sedimentary bottoms with a low amount of pelite fraction (<30%); limited use in vulnerable and protected habitats	all mobile sedimentary bottoms
no. of HT and community parameters	5	7	8
sampling efficiency (no. #samples/ fieldwork)	1	1	24
analyses efficiency (no. of hours/#sample)	15	8	8
taxonomy precision	high	lower	lower
taxa detection	high, including smaller cryptic species	low	lower, includes more highly vagile and retractable species
sample storage	hard/impossible (big volume, material, maintenance)	easy (digital data)	easy (digital data)
sample reassessment	hard/impossible	easy	easy

by lower taxonomic resolution and reduced detectability of small or cryptic species (Service & Golding, 2001; Ierodiaconou *et al.,* 2011).

The observed discrepancies among methods highlight the importance of sampling bias in marine benthic ecology. Each method emphasises different components of the community, resulting in method-dependent interpretations of community structure. Dredge sampling primarily captures species richness and biomass of sediment-associated, cryptic and smaller taxa, whereas video surveys emphasise the ecological role of sessile and habitat-forming organisms as well as some highly mobile or retractable. Consequently, reliance on a single method may lead to incomplete or potentially misleading ecological conclusions (Bowden & Hewitt, 2012).

A key outcome of this study is the pronounced complementarity among the two sampling approaches. Each method contributed unique information, with only partial overlap in detected taxa. Dredge sampling accounted for most unique taxa, while video-based methods identified a smaller but distinct subset not captured by dredging. This complementarity clearly indicates that no single method is sufficient for a comprehensive characterization of epibenthic communities.

The integration of destructive and non-destructive approaches therefore provides a more robust and holistic assessment by combining high taxonomic resolution with improved spatial coverage and ecological context (Solan *et al.,* 2003; Jørgensen *et al.*, 2011). Such multi-method strategies have been widely recommended in benthic research to reduce uncertainty in biodiversity estimates and strengthen ecological interpretation (Bowden & Hewitt, 2012).

These findings have direct implications for benthic monitoring programmes. While there is an increasing shift towards non-destructive video and spatially extensive methods such as video surveys, their limitations in taxonomic resolution must be acknowledged. Conversely, dredging provides detailed taxonomical information but is invasive and spatially restricted. A combined methodological framework therefore represents the most balanced approach, enabling both more precise taxonomic assessment and broader habitat evaluation, resulting in better detection of ecological changes and supporting more effective ecosystem-based management strategies. This is even more true for the northern Adriatic Sea, where previous studies have demonstrated high spatial heterogeneity and sensitivity of benthic communities to environmental gradients and human impacts (Fedra *et* *al.,* 1976; Mavrič *et al.,* 2010; Orlando-Bonaca *et al.*, 2012). The experiment with a camera mounted on the dredge did not prove sufficient combination of the two approaches, as the speed needed for a dredge to be effective turned out to be too high for a good quality of the recorded video. Besides this, the spatial extent covered in this way stayed very limited. A separate application of direct sampling and video survey thus seems the most optimal option.

The results also point to the limits of direct comparability. Comparisons among methods are inevitably influenced by differences in spatial extent, taxonomic resolution and the type of data produced by each approach. For video-based methods, image quality, visibility and observer expertise must be considered, because these factors determine whether a given taxon can be recognised and quantified at all. The next logical step is therefore the standardisation of sampling protocols and the development of analytical frameworks that allow more direct integration of physical samples and video records. Recent advances in computer vision provide an important opportunity to improve the efficiency and reproducibility of video-based benthic monitoring, particularly by reducing the bottleneck associated with manual annotation and by supporting automated detection, classification and quantification of benthic organisms in underwater imagery (Service & Golding, 2001; Ierodiaconou *et al.*, 2011; Bowden & Hewitt, 2012; Trotter *et al.*, 2025).

OCENJEVANJE EPIBENTOŠKIH ZDRUŽB MEHKEGA DNA: METODOLOŠKI VPOGLEDI V DREDŽANJE IN VIDEO PREGLEDE

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POVZETEK

Avtorji so primerjali dva pristopa k vzorčenju in oceni epibentoške združbe mehkega dna, vzorčenje z uporabo dredže ter neinvazivne preglede s kamero na dredži in z video sanmi. Vzorčenje je bilo izvedeno na detritičnem muljasto-peščenem dnu. Identificiranih je bilo 171 taksonov, pri čemer je bila med vsemi metodami skupna le manjša podmnožica. Z dredžanjem so dobili najvišje število taksonov, zlasti majhnih, kriptičnih in povezanih s sedimentom, ter podatke o biomasi. Nasprotno so z video metodama ugotovili manjše število taksonov, vendar med njimi več gibljivih vrst, številčno pa so lahko ovrednotili tudi nekatere taksone, kot so spužve. Z video pregledi so zagotovili najobsežnejšo pokritost in največje število parametrov habitata in združb. Ker se pristopa medsebojno dobro dopolnjujeta, je smiselno za celovitejše spremljanje in oceno uporabiti kombinacijo obeh.

Ključne besede: epibentos, cirkalitoral mehkega dna, dredžanje, kamera na dredži, video sani, Jadransko morje

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HABITAT INSIGHTS FOR THE EUROPEAN POND TURTLE (*EMYS ORBICULARIS*) IN THE COASTAL WETLAND AREA SEČOVLJE SALINA NATURE PARK, SLOVENIA

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ABSTRACT

*A comprehensive study was conducted in the Sečovlje Salina Nature Park, one of the largest coastal brackish areas in Slovenia, to investigate the habitat requirements of the European Pond Turtle (*Emys orbicularis*). During 2019-2020, five female turtles were monitored using GPS solar-powered telemetry transmitters. Based on the high-resolution LiDAR data and spatial analysis, the study aimed to compare the activities of individual turtles on a monthly and hibernation basis across two ecologically distinct but neighbouring areas within the park. The data collected over such a short (monthly) period provides valuable insights into habitat requirements, seasonal spatial dynamics, and the contrasting environmental conditions. The findings contribute essential baseline information for understanding and developing future conservation strategies for this endangered species in coastal brackish wetlands, which tend to be locally specific and vulnerable to numerous human-induced pressures.*

Key words: European Pond Turtle, *Emys orbicularis hellenica,* GPS-telemetry, LiDAR, habitat use, conservation management, coastal wetland

APPROFONDIMENTI SULL'HABITAT DELLA TESTUGGINE PALUSTRE EUROPEA (*EMYS ORBICULARIS*) NELL'AREA UMIDA COSTIERA DEL PARCO NATURALE DELLE SALINE DI SICCIOLE, SLOVENIA

SINTESI

*Gli autori hanno condotto uno studio approfondito nel Parco naturale delle Saline di Sicciole, una delle più grandi aree costiere salmastre della Slovenia, per indagare i requisiti di habitat della testuggine palustre europea (*Emys orbicularis*). Durante il periodo 2019–2020, cinque femmine di tartaruga sono state monitorate mediante trasmettitori GPS a energia solare. Sulla base di dati LiDAR ad alta risoluzione e di analisi* *spaziali, lo studio ha avuto l'obiettivo di confrontare le attività dei singoli individui su base mensile e durante il periodo di ibernazione, in due aree ecologicamente distinte ma confinanti all'interno del parco. I dati raccolti in un periodo relativamente breve (mensile) forniscono informazioni preziose sui requisiti di habitat, sulle dinamiche spaziali stagionali e sulle condizioni ambientali contrastanti. I risultati contribuiscono con informazioni di base essenziali per la comprensione e lo sviluppo di future strategie di conservazione per questa specie minacciata negli ambienti umidi costieri salmastri,*

Parole chiave: testuggine palustre europea, *Emys orbicularis hellenica*, telemetria GPS, LiDAR, uso dell'habitat, gestione della conservazione, zona umida costiera

INTRODUCTION

Knowledge of habitat distribution across space, including changes over time, is crucial to management and conservation initiatives in times of massive biodiversity loss (Böhm *et al.*, 2013). Landscape composition across space has wide-ranging effects on species because it determines the right climatic, elevation, or soil conditions suitable for the physiological requirements of species (Böhm & Popescu, 2016). Habitat loss is one of the leading causes of biodiversity loss. Thus, habitat assessments delineating a critical habitat for the protection or improvement of habitat quality for a species are crucial to conservation.

Compared to other vertebrates, reptiles, especially freshwater turtles, are scarcely represented in landscape ecology (Böhm & Popescu, 2016). While freshwater turtles tend to have narrower habitat requirements than other vertebrates, they still require a relatively large area to meet their diverse needs (Ficetola *et al.*, 2004; Rogner, 2009; Böhm *et al.*, 2013; Lovich *et al.*, 2018). Comparative studies on habitat use (Slavenko *et al.*, 2016) indicate that the required area for normal activity, known as home range (Burt, 1943), of freshwater turtles (species that spend most or a significant amount of time in water), can range from 0.013 ha (*Kinosternon acutum*; Iverson & Vogt, 2011) to up to 327.6 ha (*Trachemys scripta;* Jaeger & Cobb, 2012). Semi-aquatic behavior, which is one of the main characteristics of the genus *Emys*, indicates the need for larger areas based on specific aquatic, riparian, and terrestrial habitat requirements (Ficetola *et al.*, 2004; Mitrus, 2010). Both a location switch and consistent fidelity to specific locations have been observed during daily and seasonal cycles while analysing the main turtle behaviors, such as sun-basking, feeding, mating, egg-laying, overland migrations and hibernation (Lebboroni & Chelazzi, 1991; Kotenko, 2000; Zuffi, 2000; Dall'Antonia *et al.*, 2001; Meeske & Muhlenberg, 2004; Novotný *et al.*, 2004; Ottonello *et al.*, 2005; Ficetola & De Bernardi, 2006; Rogner, 2009; Vignoli *et al.*, 2015; Erdélyi *et al.*, 2019; Marchand *et al.*, 2021). In addition to the behavioral aspects, the complementarity of the habitat use is also strongly correlated with the developmental stage of a species (Lebboroni & Chelazzi, 1991; Cadi *et al.*, 2004; Meeske & Muhlenberg, 2004) and is associated with biotic or physical constraints (Cadi *et al.*, 2004; Meeske & Muhlenberg, 2004; Slavenko *et al.*, 2016), which can vary in the distribution area of a species. Information on habitat requirements for the endangered European Pond Turtle, *Emys orbicularis* (Linnaeus, 1758), is very limited, especially for coastal brackish habitats (Lebboroni & Chelazzi, 1991; Liuzzo *et al.*, 2023). This deficit in information is surprising, as ongoing conservation efforts in coastal wetlands are urgently needed. Conservation management constantly faces numerous conflicts of interest related to humans, especially habitat destruction and fragmentation, invasive species, and climate change, exacerbating challenging conditions during hot and dry summers (Moravec, 2003; Fattizzo, 2004; Broggi & Grillitsch, 2012; Žagar *et al.*, 2013; Standfuss *et al.*, 2016; Ivajnšič *et al.*, 2017).

In Slovenia, the European Pond Turtle is an endangered and fully protected native turtle species (Official Gazette of the Republic of Slovenia, No. 46/2004, with amendments; Habitat Directive, 1992; Bern Convention, 1979; Official Gazette of the Republic of Slovenia, No. 82/02, with amendments). According to Vamberger *et al*. (2015), the Slovenian populations match the morphological and genetic characteristics of the two subspecies: *E. o. orbicularis* and *E. o. hellenica*. The nominate subspecies *E. o. orbicularis* inhabits a wide range of Slovenia, whereas the subspecies *E. o. hellenica* is more closely restricted to the Mediterranean climate and is present in the Slovenian part of Istria and its hinterland (Vamberger *et al*., 2015; Žagar *et al*., 2019). One of the major *E. o. hellenica* populations inhabit the Istrian coastal wetland area Sečovlje Salina (Fritz, 2003; Tome, 2003). In 2003, the population in Sečovlje Salina with the Dragonja River estuary was estimated to represent 1-5 % of the Slovenian population according to limited findings (Škornik, 1990-1991; Tome, 1996, 2003). Despite several recent studies (Škornik, 2005; Vamberger, 2009; Torkar, 2012; Budak, 2013; Torkar & Ferjančič, 2013; Ferjančič & Škornik, 2018; 2019), some biological aspects, such as habitat use, remain under-researched across the entire distribution range. Furthermore, our knowledge of the habitat use of other Slovenian *E. o. hellenica* populations in coastal brackish areas (Leban *et al*., 2021) or internal riverine and marshy plains (Pekolj *et al*., 2021; Lipovšek & Vamberger, 2021) remain incomplete. This lack of knowledge hinders the adequate protection and management of this species.

Telemetry is an essential method for collecting data on habitat requirements using tracking devices based on various technologies (Joo *et al*., 2020; Crane *et al*., 2021). VHF (very high frequency) radiotelemetry is common in terrestrial reptile research and seems to be the predominant tracking method for valuable insight into habitat requirements, also for freshwater turtles with semi-aquatic behavior (Crane *et al*., 2021). Automated or GPS (Global Positioning System) logging devices remain relatively rare in reptile research despite the growing popularity in the last decade also as a cost- and time-efficient approach (Joo *et al*., 2020; Crane *et al*., 2021; Čonč *et al*., 2022). Furthermore, for studying the movements of freshwater turtles, GPS-telemetry enables more accurate delineation of movement paths, reveals the timing of movements between habitats, and allows data collection without researcher interference with the turtle's movements (Christensen & Chow-Fraser, 2014). However, all recent studies on tracking the movements of *Emys orbicularis* are based on radiotelemetry (Mascort & Budo, 2017; Drechsler *et al*., 2018; Escoriza *et al*., 2020; Horváth *et al*., 2021; Liuzzo *et al*., 2023), including research conducted in Slovenia (Vamberger & Kos 2011; Pekolj *et al*., 2021).

We used GPS telemetry, high-resolution LiDAR, and spatial data to gain valuable insights into the utilization of aquatic and terrestrial habitats by the European pond turtle in the protected coastal wetland of Sečovlje Salina. Individual turtle activities and habitat use were compared on a monthly basis during the active season and during hibernation to obtain detailed and accurate information on habitat requirements. One of the main objectives of this study was also to estimate the differences in the spatial ecology of turtles living in different environments within the protected area. The data collected over such a short timeframe (monthly) provides valuable insights for understanding and developing future conservation strategies for this endangered species in coastal brackish wetland environments, which are locally specific and vulnerable to numerous human-induced environmental pressures.

MATERIAL AND METHODS

Study area

The field study was conducted in the Sečovlje Salina Nature Park (~ 45°29′ N, 13°37′ E; hereafter: SSNP), located in the southwestern part of Slovenia, the southernmost stretch of the Piran Bay (northern Adriatic coast) at the Dragonja River mouth (Fig. 1). Based on the physical-geographical classification of Europe accounting for climate, rocks, soil characteristics, the area belongs to the Mediterranean region (Perko *et al*., 2021). The approximately 674-ha large, protected area with no settlements or inhabitants was established at the state level in 2001. As a typical saline ecosystem with marine, hypersaline, brackish, and freshwater environments, SSNP hosts numerous rare, threatened, and endemic species and is considered to have significant national and international value (Škornik, 2012; Turk, 2019; Official Gazette of the Republic of Slovenia, No. 48/04, with amendments; Official Gazette of the Republic of Slovenia, No. 111/04, with amendments). Following the Habitat Directive (Habitat Directive, 1992), two Natura 2000 sites in the SSNP have also been designated for conservation of *Emys orbicularis*: the Sečoveljske soline in estuarij Dragonje (site code: SI3000240) and the Kanal Sv. Jerneja (site code: SI3000239). The base of the Salina is covered with up to a 90-m thick layer of sediments (Ogorelec *et al*., 1981). The hinterland of the SSNP is represented by a predominantly flat Dragonja river valley, with a simple geological structure composed of flysch rocks, limestone, and fluvial deposits (Čonč, 2020). Higher altitudes surrounding the SSNP consist of flysch hills in the west and northwest and a karst plateau in the east (Čonč, 2020; Stepišnik, 2022). The climatic conditions are coastal sub-Mediterranean, with an average annual temperature of 13.8 °C and average annual precipitation of 958 mm (Ogrin *et al*., 2023).

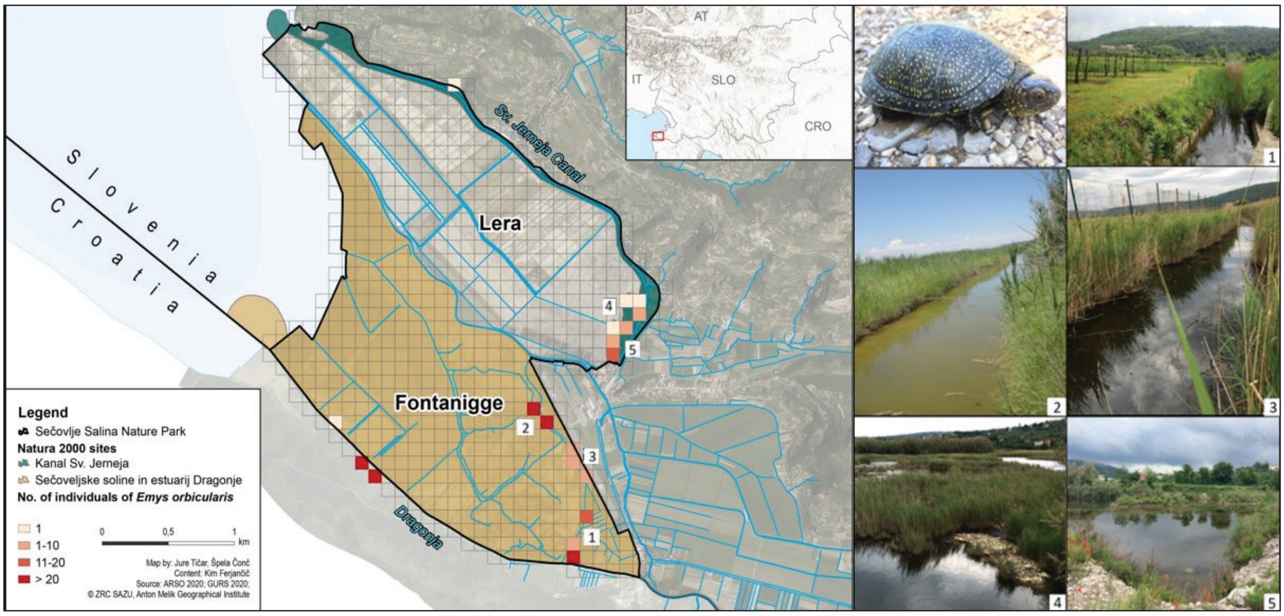

Fig. 1: The number of captured European Pond Turtle** (E. orbicularis) **in the Sečovlje Salina Nature Park and its hinterland (according to Polajnar Hrovat** et al.**, 2022). 1 – Stojbe Ditch; 2 – Alto ditch; 3 – Airport ditch; 4 – larger marsh in the Mining area; 5 – pond in the Mining area.

Sl. 1: Število ujetih močvirskih sklednic** (E. orbicularis) **v Krajinskem parku Sečoveljske soline z zaledjem (po Polajnar Hrovat in sod., 2022). 1 – kanal Stojbe; 2 – kanal Alto; 3 – kanal Letališče; 4 – večje močvirje na območju Rudnika; 5 – bajer na območju Rudnika.

The SSNP is divided arbitrarily into connected Lera and Fontanigge areas, with delineated smaller areas that primarily represent specific aquatic or terrestrial habitats (Škornik, 2012). This study followed the same site separation and focused on parts of the SSNP with the highest occurrence of *Emys orbicularis*. These parts include the marshy brackish so-called Mining area (also known as "Korea") in the southeastern part of the Lera area and the southern Salina edge of the Fontanigge area, which has artificial drainage brackish ditches, especially in the Stojbe, Alto, and Airport areas (Fig. 1). In the Mining area (maximum water surface up to 3.5 ha), turtles were found in two smaller, mostly open ponds or in a larger, densely vegetated marsh. Some shallow parts of the marsh can dry out in summer. The upper part of the nearby canal Sv. Jerneja is also considered as a part of this "pond-like" Lera area (hereafter: Lera area). Based on occasional measurements, the salinity ranged between 2.00-14.97 PSU, depending on the season and water level. The "canal-like" Fontanigge area (hereafter: Fontanigge area) consists mostly of shallow ditches with well-vegetated banks. The Stojbe ditch may dry out during summer, while the Alto and Airport ditches have a more stable hydroperiod. The salinity in these two ditches could rise to 40 PSU during the summer months. The banks around the Alto ditch were repaired multiple times to prevent saltwater intrusions, and a new shallow brackish water surface was created in 2019 (Škornik, 2012; Ferjančič & Škornik, 2018; I. Škornik, pers. comm.). *Phragmites australis* is a dominant plant in all areas where turtles mainly occur. It usually coexists with other halophytic aquatic (*e.g.*, *Ruppia cirrhosa*) and riparian plant communities (*e.g.*, *Suaeda maritima, Juncus maritimus, Carex extensa*); in some places, it is often replaced by *Arundo donax* (Kaligarič, 1990; Jogan, 2001; Škornik, 2012).

Trapping and GPS tracking

Five females captured during regular monitoring using baited funnel traps were selected for telemetry: three in the Lera area and two in the Fontanigge area (Ferjančič & Škornik, 2019). The sites of the captured turtles were recorded using a handheld GPS device (Garmin). All females were measured, weighed, photographed, aged (Meeske, 2006; Vamberger & Kos 2011), and marked by marginal notching (Kuchling, 1987). They were also palpated to detect the presence of eggs (Vamberger *et al.*, 2017). Solar-powered telemetry transmitters (Milsar RadioTag-14; Anonymous, 2024b) were attached to the anterior upper carapace margin of each female using an epoxy plumber (Pattex Epoxy Kit). As the weight of the RadioTag-14 transmitter was less than 5% of the female body mass, the influence of the tag was considered minimal (Knapp

& Abarca, 2009; Bayrakçı *et al.*, 2021). The tagged females were released into the water at the capture site within 30 minutes.

The telemetry data was collected from the first half of April 2019 until the end of June 2020. Data were automatically downloaded on a weekly basis using a radio download feature (base station) based on Milsar software (Anonymous, 2024b) without the need to recapture the turtle. The maximum range for downloading data in the line of sight (with no obstacles between the base station and transmitter) was estimated to be less than 3 km. The data collection intervals were set between 5 and 15 min. The variables recorded by the telemetry transmitters with estimated error < 10 m (Milsar, *pers. comm.*) were latitude, longitude, time, and date (Appendix 1).

Home range, movements, and habitat use

The analysis of home range, movement, and habitat use was based on separate monthly telemetry data obtained during the period of activity and grouped hibernation months during the period of hibernation. These periods were not defined in advance based on the observations but rather determined accordingly to the gathered telemetry data. Telemetry data of turtles were not pooled but analysed separately. All applied analyses were based on the same gathered data of cleaned (expert‘s decision) tracking locations. Only turtles with available tracking data for both years, including those for hibernation, were considered representative and used in all analyses. Information from tracked females with less available data was used solely for comparison purposes.

Home ranges were calculated using the Minimum Convex Polygon (MCP; Mohr, 1947) and Kernel Density Estimation (KDE; Worton, 1989), which are the most frequently used geometric methods in reptile home range studies (Crane *et al.*, 2021). The home range sizes for the entire study period were calculated using the Minimum Convex Polygon (MCP) method, employing both 100% of all telemetry records (hereafter: MCP 100%) and 95% of the records (hereafter: MCP 95%). To allow comparison with similar studies, the home range for the entire study period was also estimated using the 95% counter level by the KDE method (hereafter: KDE 95%). A fixed bivariate normal KDE with h_{ref} as the smoothing factor (default reference bandwidth) was used for the KDE calculation. For monthly and hibernation home range size calculations, only the MCP 95% method was used, as it has been used in the literature for *Emys orbicularis* (Cadi *et al.*, 2004; Thienpont *et al.*, 2004; Liuzzo *et al.*, 2023). All calculations were conducted in R (version 4.3.1; R Core Team, 2023) using the packages "adehabitatHR" and "adehabitatLT" (Calenge, 2006, 2023) with sp (Pebesma & Bivand, 2005) and sf (Pebesma, 2018) for the spatial data processing. As home range size estimations did not meet the parametric assumptions, the Aligned Rank Transform (ART) ANOVA test was used to examine the effect of months and to test the difference between areas. Furthermore, the interaction between months and areas was also investigated (Wobbrock *et al.*, 2011; Kay & Wobbrock, 2023). The relationship between the number of locations and home range was analysed using Spearman Correlation (Drechsler *et al.*, 2018; Liuzzo *et al.*, 2023).

All telemetry data collected for each turtle were used to create trajectories, which are defined as the paths connecting the relocations of the tracked turtles. The daily mean distances traveled were analysed based on the distance parameter of the created trajectory. The trajectories were created in R (version 4.3.1; R Core Team, 2023) using the package "adehabitatLT" (Calenge, 2006, 2023; Paterson, 2018). The Mann-Whitney test was used to evaluate differences in mean monthly/hibernation movement distances between the Lera and the Fontanigge areas.

Turtle habitat use was analysed based on 11 predictor covariates, which were categorized into two groups: topographical and environmental/anthropogenic (Appendix 2). All variables were mapped and analysed in ArcGIS Pro 3.0.3 (ESRI, Redlands, CA, USA). Calculation of topographical predictors was based on the spatial analysis of a high-resolution digital terrain model (hereafter: DTM; 1 m × 1 m). To create a DTM, LiDAR data obtained from aerial laser scanning was used, consisting of a cloud of ground points (LAS files) provided by the Slovenian Environment Agency (ARSO). The aspect, slope, solar radiation (SR), Topographic Wetness Index (TWI), Terrain Ruggedness Index (TRI), and Vector Ruggedness Measure (VRM) were calculated based on the LiDAR-derived DTM. Values of topographical predictors were categorized into five classes based on Jenks' natural breaks (1 = very low, 2 = low, 3 = moderate, 4 = high, 5 = very high). Environmental/anthropogenic predictors were also included: length of waterway and cycling path, area of lentic and lotic water bodies, and land use categories (Appendix 2). Data were provided by the Ministry of Agriculture, Forestry, and Food (MKGP, 2023), Municipality of Piran, and Slovenian Water Agency (DRSV). Habitat use was analysed separately for the Lera and the Fontanigge areas based on all gathered telemetry data for a given turtle (MCP 100 % for the entire study period). Each turtle's location was associated with the covariate range/category. Statistically significant differences in habitat use were tested on a monthly/hibernation basis. Due to the data not meeting parametric assumptions, a non-parametric Chi-Square test with *post hoc* residual analysis and Kruskal-Wallis tests with *post hoc* Mann-Whitney tests were used. To account for differences between months and compared turtles, a sequentially rejective Bonferroni test was applied in all *post hoc* analyses (Holm, 1979; Delucchi, 1993). Although Chi-square tests were conducted on frequency data, the results are presented as proportions to facilitate interpretation. All statistical analyses were carried out using SPSS (IBM SPSS Statistics 21), with an alpha level set at 0.05.

RESULTS AND DISCUSSION

General observations of GPS-telemetry

During the study, five females in a good state of health (no detected physical or locomotory abnormalities), with straight-line carapace lengths ranging from 128 to 162 mm and body mass from 383 to 670 g, were tracked using GPS telemetry (Appendix 1). A total of 8597 GPS tracking locations were collected, with varying tracking frequencies. Some tags only produced one location per day or none for several consecutive days, presumably because the transmitters did not transmit data when the turtles were submerged underwater. The locations were recorded over at least 414 days for each turtle. The tracking frequency ranged from 1 to 48 locations per day. Only two turtles with available data for both years, including those for hibernation, were considered representative and used in all analyses: the adult female named Berta (tag number: 999003) and the adult female named Nevija (tag number: 999006). Berta, with an average tracking frequency of 16 locations per day with received signal (April 2019-June 2020; 4038 locations over 193 days with received signal) was set as representative for the Lera area and Nevija, with an average tracking frequency of 20 locations per day with received signal (May 2019-June 2020; 3440 locations over 155 days with received signal) was set as representative for the Fontanigge area. Data from other tracked females (Alta, Loredana, and Rudica), with available telemetry data for 2-4 months, were used for comparison purposes only (Appendix 1).

The months of activity and the hibernation period were set based on the GPS telemetry. In the Lera area, the end of the activity period was determined based on the most recent data downloaded from Berta in 2019 (19/11/2019), which indicated that the activity period concluded around mid-November 2019. The start of the active period in 2020 was most likely in the beginning of April ($n_{GPS} = 313$; 3/04/2020-30/04/2020) because only a few GPS locations were obtained at the end of February ($n_{GPS} = 5$; 26/02/2020-28/02/2020) and at the beginning of March ($n_{GPS} = 4$; 3/03/2020-08/03/2020). The highest number of locations was obtained in July ($n_{GPS} = 1{,}299$). In the Fontanigge area, the last datum downloaded by Nevija in 2019 was at the beginning of September (11/09/2019), while the first received signal in 2020 was from the beginning of March (03/03/2020). The low number of GPS locations obtained in March ($n_{GPS} = 20$; 03/03/2020-20/3/2020) most likely indicates the start of the active period at the beginning of April ($n_{GPS} = 515$; 05/04/2020-30/04/2020), similar to the Lera area. The highest number of recorded locations was in June ($n_{GPS} = 1189$). The results from the telemetry data for both the active (from April to the first half of November in Lera and from April to August in Fontanigge) and hibernation (from the second half of November to March in Lera and from September to March in Fontanigge) periods are quite different from those of the central part of Slovenia. Vamberger & Kos (2011) reported that the period of activity of the European Pond Turtle in Ljubljansko barje starts from late February to early March, and the hibernation period from around the second half of October to the beginning of November. Despite expectations of an early end to the hibernation period in 2020 due to favorable weather conditions, especially higher air temperatures and prolonged sunshine compared to the long-term average (1999-2020; Anonymous, 2024a), it is most likely that the tracked turtle's activity resumed at the beginning of April.

Home range

The calculated home range sizes (Tab. 1) during the entire study period were generally larger in Fontanigge (26.3 ha according to 100% MCP and 7.9 ha/5.0 ha according to 95% MCP/KDE) compared to Lera (23.3 ha according to 100% MCP and 4.6 ha/4.4 ha according to 95 % MCP/KDE). Furthermore, the estimated MCP 95% during the activity period was also larger in Fontanigge (2.0 ± 1.92 ha) compared to Lera (1.8 ± 1.36 ha). The opposite was observed for the hibernation period, with a larger home range estimated in Lera (0.9 ha according to 95% MCP) compared to Fontanigge (0.1 ha according to 95% MCP). Additionally, the monthly MCP 95% based on pooled data from all turtles was smaller than the sizes of individual representative turtles in both areas. There was no statistically significant difference in the home range size estimates between the two areas ($F = 2.51$, $p = 0.139$) or among months ($F = 2.86$, $p = 0.063$). However, the interaction between the area and months was statistically significant ($F = 3.33$, $p = 0.041$), indicating that monthly variation in home

Tab. 1: Home range size estimations for the representative European Pond Turtles** (E. orbicularis) **in the Lera (turtle Berta) and in the Fontanigge (turtle Nevija) in the Sečovlje Salina Nature Park. Results are presented for the entire study period (2019-2020) and monthly/hibernation period based on Minimum Convex Polygon (MCP) and Kernel Density Estimation (KDE) methods. *href as the reference default bandwidth. **All tracked females.

Tab. 1: Ocene velikosti domačega okoliša dveh izbranih samic močvirske sklednice** (E. orbicularis) **na območjih Lere in Fontanigg v Krajinskem parku Sečoveljske soline. Rezultati so prikazani za celotno obdobje raziskave (2019–2020) ter za mesečno/hibernacijsko obdobje na podlagi metod minimalnega konveksnega poligona (MCP) in metode jedrne gostotne ocene (KDE). *href kot referenčna privzeta širina pasu. **Vse sledene samice.

Method	**Period**	**Lera area**	**Fontanigge area**
MCP 100% (ha)	entire study period	23.28	26.27
MCP 95% (ha)	entire study period	4.62	7.93
KDE 95% (ha)*	entire study period	4.40 (h_{ref}= 14.29)	5.02 (h_{ref}= 15.27)
Monthly MCP 95% (ha)	activity period	1.77 ± 1.36 (0.05-3.92)	1.98 ± 1.92 (0.14-5.21)
Hibernation MCP 95% (ha)	hibernation period	0.87	0.11
Monthly MCP 95% - all turtles (ha)**	activity period	1.36 ± 1.32 (0.05-3.92)	1.80 ± 1.86 (0.08-5.21)

range size differs between Lera and Fontanigge. *Post-hoc* pairwise comparisons (Holm-adjusted) did not identify any statistically significant differences between specific area–month combinations (all $p > 0.05$), suggesting that the significant interaction likely reflects subtle, area-specific seasonal trends. The correlation between the size of the home range and the number of locations for turtles with >10 locations was positive and strongly significant (n = 25; Spearman Correlation Test, R = 0.88, $p < 0.001$).

The difference in home range sizes between areas could be attributed to the different habitat features. The smaller home ranges based on 95% locations (MCP 95%) in the pond/swamp Lera area (Tab. 1) are probably associated with a more stable hydroperiod, a greater variety of nearby aquatic habitats with predominant stagnant water bodies, and the possibility of retreating in deeper water compared to the ditch/canal Fontanigge area. Another contributing factor could be the lower salinity in the Lera area, with a maximum salinity level of 15 PSU (Ferjančič & Škornik, 2018). Previous research reports occasions with salinity levels as high as 40 PSU in almost all ditches in the Fontanigge area, with captured turtles found in water with salinity levels up to 30 PSU (Ferjančič & Škornik, 2018). These salinity levels are among the highest ever recorded for this species (Lebboroni & Chelazzi, 1991; Liuzzo *et al.*, 2023). However, it is important to note that these observations were based on limited data within SSNP (Ferjančič & Škornik, 2018), and detailed salinity monitoring could offer further valuable insights into the salinity tolerance of this species. Additionally, when considering the mechanism of adaptation to brackish or salty environments (Agha *et al.*, 2018), it would be beneficial to increase the number of tracked individuals or extend the tracking period to confirm whether the behavioral pattern of the population in SSNP corresponds with recent findings on the behavioral ecology of the Venetian *Emys orbicularis* population, which suggests that turtles tend to avoid brackish environments during hibernation and prefer higher salinities during active periods (Liuzzo *et al.*, 2023). Limited findings suggest that turtles in the Fontanigge area prefer the same brackish aquatic habitats throughout the year, despite the availability of nearby water bodies with lower salinity (Dragonja and Drnica canal, Stojbe ditch; Ferjančič & Škornik, 2018). Furthermore, the estimations based on the KDE 95 % in both areas were different from those of the other turtle populations in Slovenia (6.57 ha; Vamberger & Kos, 2011). This result may suggest limited suitable habitat conditions nearby compared to the Ljubljansko barje. It is likely that the turtles inhabited a significant part of the Dragonja River valley in the past and were forced to find smaller secondary habitats on the edge of the salt pans after the extensive land reclamation interventions.

Home range estimations indicate that turtle Berta in the Lera area utilized a wider variety of water habitats compared to turtle Nevija in the Fontanigge area. During its active period, Berta

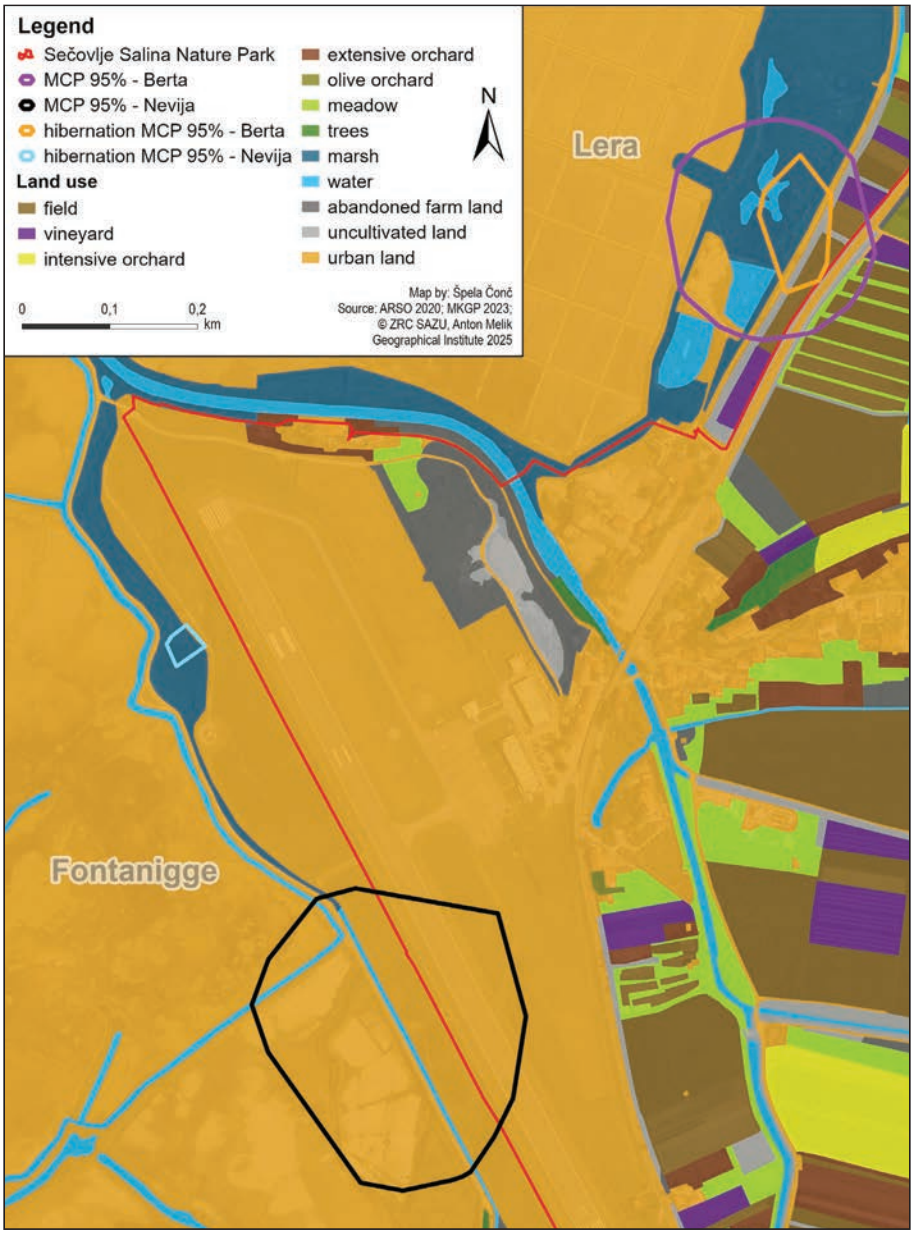

Fig. 2: Home range areas for the representative European Pond Turtles** (E. orbicularis) **obtained from 95 % of locations calculated with the Minimum Convex Polygon method in Lera (turtle Berta) and in Fontanigge (turtle Nevija) in the Sečovlje Salina Nature Park.

Sl. 2: Območja domačega okoliša dveh izbranih samic močvirske sklednice** (E. orbicularis)**, izračunana iz 95 % lokacij z metodo minimalnega konveksnega poligona (MCP), na območjih Lere in Fontanigg v Krajinskem parku Sečoveljske soline.

was observed in a larger marsh, a smaller pond, ditches along the salterns' edge, and the canal Sv. Jerneja. During the hibernation period, Berta was primarily seen in the larger marsh and canal Sv. Jerneja. In contrast, Nevija in the Fontanigge area was active in the ditches of the Alto and Airport regions, as well as in a shallow water pool along the Alto's ditch. During its hibernation period, Nevija was found only in the upper part of the ditch in the Airport area (Fig. 2). Notably, the home ranges of the two turtles did not overlap during either the active or the hibernation periods, despite previous observations of movements between areas (Ferjančič & Škornik, 2018).

Due to the limitations of acquiring tracking data, the size and location of the home range during hibernation should be carefully interpreted. Only a limited number of locations were identified between October and March. The estimated home range size during hibernation obtained from 95% of locations in the Lera area is comparable with estimates from France (0.74 ha; Thienpont *et al.*, 2004). On the other hand, the estimates in Fontanigge, obtained using the same method, are more comparable with estimates from Italy (mean ± 1 SD: 0.13 ± 0.11 ha; Liuzzo *et al.*, 2023). In Lera, the location of Bertas’ home range during hibernation coincided with its home range during the activity period, like the observations of Novotný *et al.* (2008) observed in Slovakia. However, in Fontanigge, turtle Nevija migrated at least 300 m away from its active season site to hibernate in deeper waters, which resembles the findings of Thienpoint *et al.* (2004) in France (Fig. 2). Our findings indicate that turtles in SSNP do not concentrate only in one area to hibernate, as suggested by Vamberger and Kos (2011) in the Ljubljana marsh area. Therefore, identifying both the period and the sites selected for hibernation is crucial for the species‘ long-term survival, especially due to observed aggregation during hibernation and high site fidelity to the overwintering site (Schneeweiss *et al.*, 1998; Meeske, 2000; Mazanaeva & Orlova, 2004; Thienpont *et al.*, 2004; Vamberger & Kos, 2011).

Movement results

The mean distances traveled per day were quite similar in both areas (n = 7477; Mann-Whitney U = 6920991; p = 0.81). The calculated mean daily distances during the entire study period were slightly longer for the turtle Berta in Lera (ranging from 12.23 ± 8.14 m to 49.63 ± 18.35 m) compared to those of the turtle Nevija in Fontanigge (ranging from 11.04 ± 12.98 m to 38.67 ± 59.60 m; Fig. 3). For both turtles, the longest mean distance traveled per day was calculated for March. A slight peak in the mean distance traveled per day was observed in June (≈ 30 m), followed by a notable increase in the autumn for both turtles (>30 m). Turtle Berta in Lera exhibited longer daily mean distances in October and November, while turtle Nevija in Fontanigge only in September. The maximum distance traveled in a day was recorded for turtle Berta in June (560.02 ± 45.58 m) and for turtle Nevija in

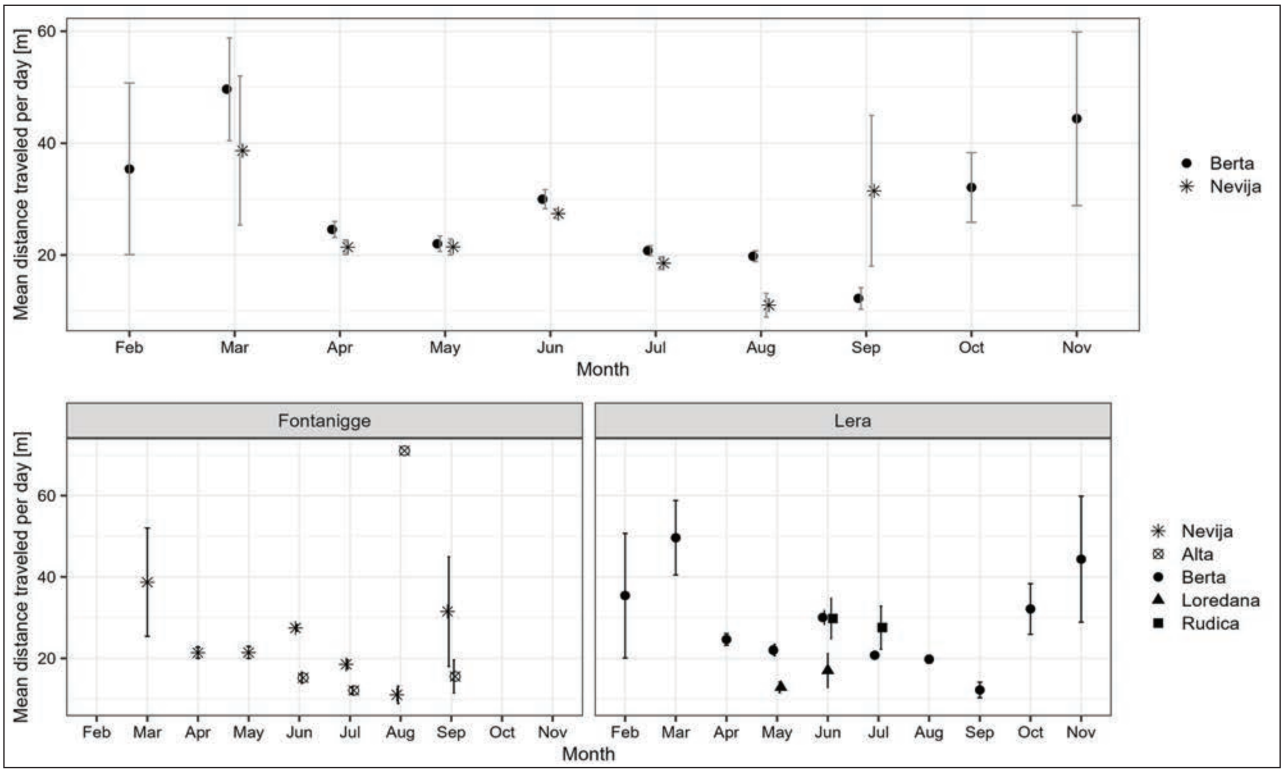

Fig. 3: Mean distance traveled per day with standard deviation for European pond turtles** (E. orbicularis) **in Lera and Fontanigge in the Sečovlje Salina Nature Park.

Sl. 3: Povprečna dnevna prepotovana razdalja s standardnim odklonom pri močvirskih sklednicah** (E. orbicularis) **na območjih Lere in Fontanigg v Krajinskem parku Sečoveljske soline.

September (585.44 ± 89.35 m). In addition, the monthly mean distances traveled per day were shorter compared with other turtles for almost all months (ranging from 12.10 ± 13.09 m to 29.74 ± 22.70 m; Fig. 3).

A comparable mean distance traveled per day was calculated in both areas, despite the differences in home range (Tab. 2). The longest mean distance traveled per day in March should be interpreted with caution due to the limited number of locations during that month, which is still considered part of the hibernation period. It is assumed that the turtles primarily traveled underwater during this time. Our movement results are partly comparable with those obtained by Cadi *et al*. (2004), especially when considering the long-range movement in May and June obtained for the French population in La Serre (maximum: 520 m). Similar longest traveled distances were also reported by Liuzzo *et al*. (2023) for the Venetian population in Italy (546.64 m). The movements of turtles in our study partly resemble those observed in eastern Spain, specifically in the Albufera de Valencia Natural Park (Drechsler *et al*., 2018), where a peak in movement was observed in spring (March and April) and later again in July.

Habitat use

The analysis of habitat use for both representative females in each area revealed differences between months of the active season and the hibernation period for almost all topographical and environmental/anthropogenic covariates (Appendix 3). In Lera, the most important terrestrial land use categories for Berta were fields, uncultivated land, and urban land (each with over 1% use in all months/hibernation). Among the aquatic categories, for each month and the hibernation period, the highest number of locations was assigned to the marsh. Berta was observed every month in both lentic and lotic waters, except during hibernation (present only in the lotic waters), with the latter being predominantly selected. The highest percentage of Berta's locations assigned to waterway was recorded in September (11%), whereas in all other months, it was lower than 4%.

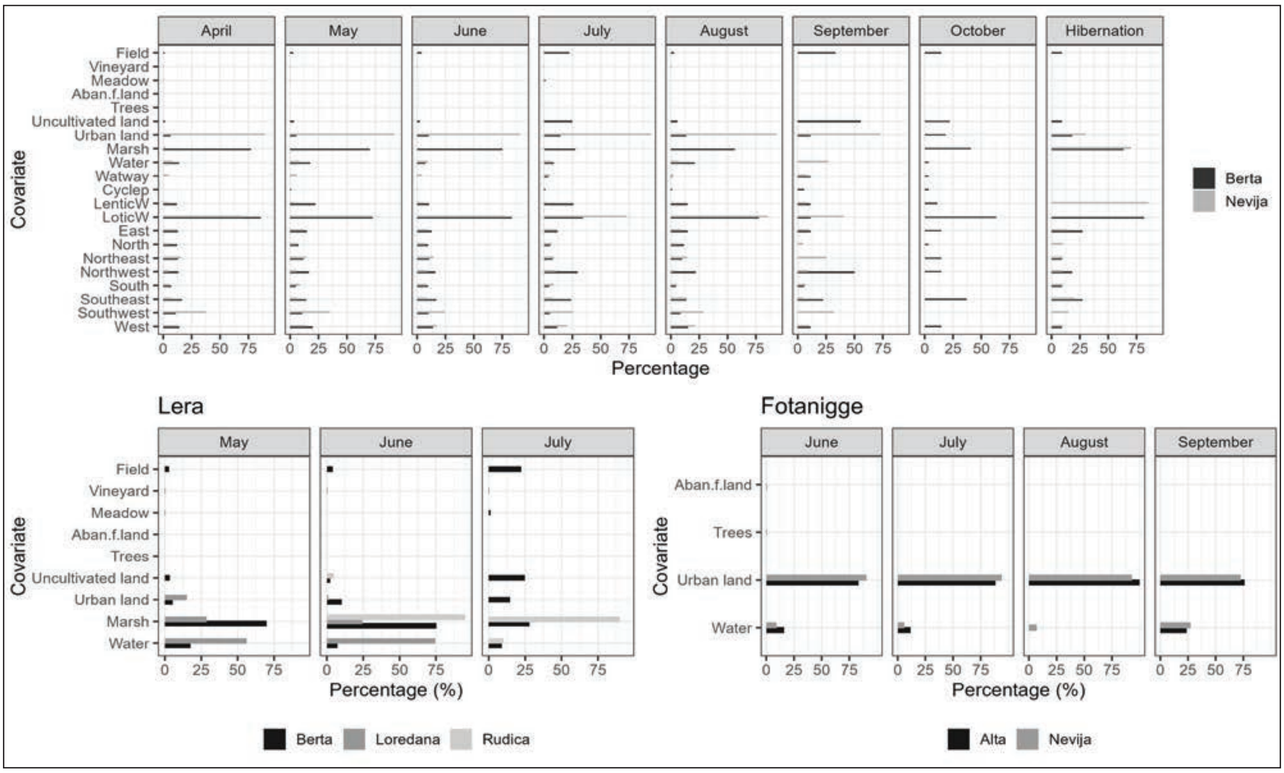

Fig. 4: The monthly/hibernation proportions of the covariate categories/range for European pond turtles (*E. orbicularis*) **in Lera and Fontanigge in the Sečovlje Salina Nature Park. Aban.f.land - Abandoned farmland; LenticW – Lentic Water, LoticW – Lotic water, Watway – Waterway, Cyclep – Cycling path.**
Sl. 4: Mesečni in hibernacijski deleži kategorij oziroma razponov kovariat pri močvirskih sklednicah (*E. orbicularis*) **na območjih Lere in Fontanigg v Krajinskem parku Sečoveljske soline. Aban.f.land – opuščena kmetijska zemljišča; LenticW – stoječe vode; LoticW – tekoče vode; Watway – vodotok; Cyclep – kolesarska pot.**

Berta was occasionally observed near or on the cycling path almost every month (0.4-5.6% of locations), except in April and during hibernation. Most of Berta's locations were documented in the northwest-facing areas during the summer months (July-September) and in the southeast-facing areas during almost all other months. During hibernation, the assigned locations mostly faced to the southeast and east, and during May to the west (Fig. 4). Throughout the year, Berta predominantly used locations with high solar radiation, very low slope and ruggedness, and locations with low potential for water accumulation (TWI). However, it is important to note that throughout the active season and hibernation, a wide range of values was observed for all these topographical covariates, ranging from very low to very high classes, even for the solar radiation (Fig. 5). In Fontanigge, most of Nevija's terrestrial locations during active months were assigned to urban land (>73%). Among the aquatic categories, the highest number of locations was assigned to water. Almost every month, Nevija was observed in both lotic and lentic waters, with the latter being predominantly selected. Lentic water was the only habitat assigned for hibernation. The highest percentage of Nevija's locations assigned to waterway was recorded in September (7%), whereas in all other months, it was lower than 6%. During the study, Nevija was not observed near or on the cycling path. Nevija's locations were mostly in the southwest-facing areas, with less variation in assigned slope values between months compared to Lera (Fig. 4). Some similarities with Lera were observed regarding the topographical covariates (*e.g.*, solar radiation, slope, and potential for water accumulation), although Nevija's locations were more often assigned to even gentler slopes and less rugged terrain. Overall, the range of assigned values for topographical covariates was narrower compared to Lera, with most falling within four classes (Fig. 5).

The monthly analysis of habitat use considering all females also revealed differences among months for almost all topographical and environmental/anthropogenic covariates in both areas (Chi-Square > 4.34 with p < 0.03 and Mann Whitney > 2,136.0

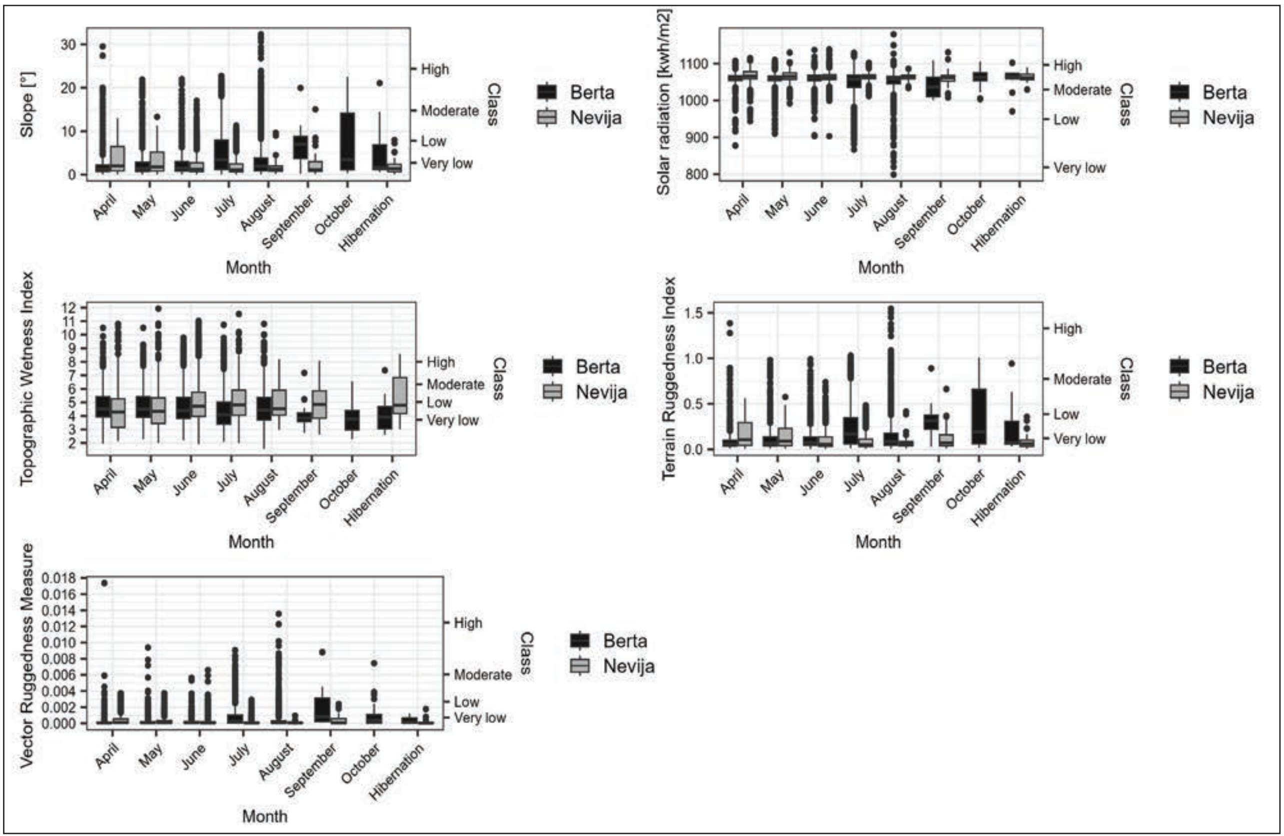

Fig. 5: Box plots of topographic covariates for European pond turtles *(E. orbicularis)* ***in Lera and Fontanigge in the Sečovlje Salina Nature Park.***

Sl. 5: Box-ploti topografskih kovariat pri močvirskih sklednicah *(E. orbicularis)* ***na območjih Lere in Fontanigg v Krajinskem parku Sečoveljske soline.***

with $p < 0.001$). Interestingly, the land use categories assigned in June and July for two other females with palpated eggs differed from those of the representative females (Fig. 4).

In both areas, the highest percentage of terrestrial locations was assigned to the urban area land category. In our study, this category primarily consists of the saline system, which includes gravel paths, saline fields, and the overgrown or cultivated banks of water habitats or embankments next to the saline fields. These surfaces within urban areas are believed to be very important for *Emys orbicularis*, as previous observations have also shown egg laying in some parts (Ferjančič & Škornik, 2018; 2019). However, the available data for this land use category do not accurately distinguish between the saline system and other infrastructure types also included in this category, such as airports, tourist areas, or other concrete surfaces. Therefore, the results should be interpreted with caution. Based on our results, we suggest that a more detailed delineation (*e.g.*, remote detection based on high-resolution aerial imagery) of land categories within the saline system (*e.g.*, gravel paths, reedbed) would substantially improve the understanding of the turtles' habitat requirements. Furthermore, such detailed identification would allow for more targeted management and protection measures.

All terrestrial locations assigned to Berta and Nevija, along with urban land, can be considered as potential egg-laying sites (Fig. 4), especially field, uncultivated land, and meadow land use categories in Lera, as well as the abandoned farmland in Fontanigge. Although only a few of Berta's locations were tracked in the vineyard land category, nesting of *Emys orbicularis* was confirmed there in one of the previous years. The locations of other females with palpated eggs were also assigned to the land categories: trees and uncultivated land (Fig. 4). Nesting sites similar to those suggested for egg-laying in our study were also observed in Slovakia (Novotný *et al.*, 2004). It seems that the closeness of fields and uncultivated land categories, besides urban land, is significant for turtles during short-term reactivation, either immediately after hibernation, most likely between February and March, or even earlier. In addition to analysing terrestrial habitats, Berta was often (1% of locations; n = 35) observed on the cycling path (Fig. 4). Furthermore, our analysis showed that turtles use suitable habitats also outside the SSNP, including agricultural areas on the other side of the road. Both lotic and lentic waters are considered important in both areas. As shown in this study, turtles can be observed crossing the cycling path, exposing them to bicycles and other small vehicles that may cause injury or mortality. Frequent daily use of the cycling path by visitors, tourists, and locals can also disturb turtles during basking, migration, or egg-laying. Because the cycling path represents one of the intensively used tourist infrastructures within or near the SSNP, we highlight the need to assess its potential negative impact and to compare it with other infrastructure types, such as gravel paths.

The analysis based on topographical factors indicated that both turtles tended to prefer areas with high solar radiation, low or very low slope and ruggedness, as well as low potential for water accumulation. However, a wide range of values for these characteristics was observed on a monthly basis and during hibernation, indicating the need for a diverse range of habitat features. Similarly, a significant diversity was also documented for the assigned aspect during the study period. No specific pattern could be identified for the assigned values for any of the topographical factors, whereas the most similar values between months/hibernation period was observed for solar radiation (Fig. 5). The assigned values for some topographical covariates (*e.g.*, aspect and slope) can mostly be compared only to values obtained from the presence records of *Emys orbicularis* and no particular deviation from those was observed (Kornilev *et al.*, 2017).

CONCLUSIONS

As already pointed out by Liuzzo *et al.* (2023), quantitative data on the habitat requirements of the threatened European Pond Turtle in saline ecosystems are urgently needed to evaluate which areas are indispensable for the species and what measures can improve habitat suitability. Our research focused on the predominantly brackish habitats in the SSNP, where the subspecies *Emys o. hellenica* lives (Vamberger *et al.* 2015). Recent data have shown a low number of younger individuals (Ferjančič & Škornik, 2018; 2019; 2021) and highlighted several threats, including the intensive use of agricultural land, park visitors deviating from marked paths (Škornik, 2016; 2017; 2018; 2019; 2020), the introduction of alien turtle species (*Trachemys scripta*; Krofel *et al.*, 2009; Torkar, 2012; Ferjančič & Škornik, 2018; 2019; Žagar *et al.*, 2019), and inappropriate timing of management measures in aquatic habitats. Due to limited funding and the observation that males and females in similar habitats do not show significant differences in movement distance and home range (Slavenko *et al.*, 2016; Liuzzo *et al.* 2023), our research focused only on females living in the Fontanigge and Lera areas, where turtles are most abundant in the SSNP (Fig. 1), which also allowed us to study reproductive behavior, as successful long-term reproduction is crucial for species conservation (Zuffi, 2000;

Ficetola *et al.*, 2004; Fritz & Chiari, 2013). Based on a comprehensive literature review, our study is among the first to use GPS transmitters on this semiaquatic turtle species (Cadi *et al.*, 2004; Meeske & Muhlenberg, 2004; Novotný *et al.*, 2004, 2008; Thienpont *et al.*, 2004; Vamberger & Kos, 2011; Perez-Santigosa *et al.*, 2013; Mignet *et al.*, 2014; Mascort & Budo, 2017; Drechsler *et al.*, 2018; Escoriza *et al.*, 2020, Horváth *et al.*, 2021; Liuzzo *et al.*, 2023). A comprehensive dataset of locations was gathered using solar-powered GPS telemetry (Appendix 1). Due to limited GPS signals when the turtles are underwater, this dataset does not provide a complete understanding of their habitat requirements throughout the year. To address this issue, it is recommended to use a solar-powered GPS system that is supplemented with an additional source of energy (for example, batteries), especially during the hibernation period, to enhance data collection. Furthermore, high-resolution LiDAR-derived topographic covariates (1 m × 1 m) were used to maximize spatial precision and minimize potential bias in habitat-use analysis, even considering minor inaccuracies (estimated errors are <10 m, depending on habitat type; Anonymous, 2024b) in GPS data. The high-resolution spatial data were retained rather than generalized, as this approach better corresponds to reality and reflects fine-scale habitat relationships (Čonč *et al*. 2024). Given the flat and homogeneous terrain of the SSNP, the small GPS error was considered acceptable (Cochrane *et al.*, 2019). While acknowledging these strengths, the study also recognizes the need to address GPS telemetry limitations in future analysis (Čonč *et al*. 2024). Temporal inconsistencies in solar-powered transmitter data (*e.g.*, when submerged underwater) and the limited number of tracked turtles were identified as the main issues, rather than spatial inaccuracy. Although the chosen method provided valuable insights into turtle habitat use, a habitat selection analysis (*e.g.*, Krupiński *et al.*, 2021) could offer a more detailed understanding of environmental preferences, if consistent data become available.

Our results, based on 95 % of locations, clearly show that the European Pond Turtle *E. o. hellenica* in SSNP requires around 4 ha in the Lera area and at least 5-8 ha in the Fontanigge area of diverse suitable aquatic and adjacent terrestrial sites to fulfil all its main biological needs. It is important to note that the method chosen to estimate home range size can impact the results (Walter *et al.*, 2015; Silva *et al.*, 2020). Therefore, to ensure comparable results, outcomes from multiple method datasets are considered. Our results not only show the difference on a monthly/hibernation basis regarding the required area for normal freshwater turtle activity (home range), movements, and habitat use, but also highlight the need for distinct conservation management on a smaller scale. This conclusion is evident in the two adjacent but different Lera and Fontanigge areas inside SSNP.

The data collected by month during the active season and during the hibernation period is extremely important for avoiding any invasive mechanical interventions, such as mulching machines, in the terrestrial areas inside the SSNP and its surroundings, especially because turtles were also observed outside the park (Fig. 2). It is essential to prevent or minimize any disturbances (MESP, 2024), particularly during the nesting season (until the eggs hatch). Based on our findings and previous observations, this nesting period is expected to occur from late June to the end of July and again from late August until early November. Furthermore, it is important to avoid the use of heavy machinery during the suggested hibernation months, from September/October until April, when the end of hibernation is suggested. The period should be extended until the end of April due to the confirmed spring emergence of hatchlings (Budak, 2013; Ferjančič & Škornik, 2021). Limitations during this time frame are particularly important because it is suggested that turtles in SSNP do not hibernate in just one area; other hibernation areas still need to be discovered. The long-term continuity of such a study, including also males and younger individuals, is crucial for preserving all hibernation areas. It would be essential to incorporate the preservation of suitable hibernation areas into the Natura 2000 Management Program as another key management strategy for species conservation (MESP, 2024). During the active months when turtles spend the most time in aquatic habitats, it is important to perform maintenance works on banks (mowing, clearing, or thinning of vegetation) and interventions (dredging and silting) according to the mosaic principle. Any interventions in water habitats during the suggested hibernation period should be prevented. Moreover, our research emphasizes the significance of placing information boards and road signs along the cycling path in the SSNP, which will help to notify park visitors and hikers about the presence of the European Pond Turtle and the potential for turtles crossing the road. Given the presence of turtles on the SSNP's opposite side of the road (Fig. 2), it is crucial to create a safe passage to reduce injuries and fatalities caused by vehicles. These incidents have already been documented. Additionally, the lower part of the Dragonja River valley, which is represented by the floodplains of both the Dragonja and Drnica rivers, could also play a crucial role in conserving the European Pond Turtle within the SSNP's hinterland. In this unprotected lowland area (approximately 758 ha), extending nearly to the village of Dragonja and the western border of the Natura 2000 area Slovenska

Istra (site code: SI3000212), turtles could be found in the main channel of the Dragonja River (Budak, 2013; Tome, 2003). Additionally, the channeled bed of the Drnica River, along with the larger canals and smaller ditches on reclaimed land, may also represent potential habitats. Although data on turtle presence have not yet been systematically collected, gathering this information will be essential for the successful long-term conservation of the species. It would also be important to follow the proposed management requirements of the species (MESP, 2024) and the suggested use of machinery in this area of the park's hinterland.

Our findings can strengthen the existing management (MESP, 2024) and guide conservation efforts to protect not only the European Pond Turtle but also other endangered species, thereby preserving essential ecological processes and components of biodiversity in SSNP. The role of the European Pond Turtle in SSNP should be seen as a potential symbol of sustainable development (Polajnar *et al.*, 2022). Its existence emphasizes the significance of connecting aquatic and terrestrial habitats (Bodie & Semlitsch, 2000; Cadi *et al.*, 2004) and contributes to ecosystem services, such as seed dispersal, nutrient cycling, and carbon storage (Lovich *et al.*, 2018). The intention of the study was also to point out the importance of wetland conservation and to encourage sustainable management based on a participatory approach to link the conservation goals with the social aspect and local economic development (Polajnar *et al.*, 2022; Smrekar *et al.*, 2022).

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Appendix 1: Summary of telemetry data of European Pond Turtles** (E. orbicularis) **tracked in the Sečovlje Salina Nature Park. *Minimum time interval. / No data.

Priloga 1: Povzetek telemetričnih podatkov močvirskih sklednic** (E. orbicularis)**, sledenih v Krajinskem parku Sečoveljske soline. *Minimalni časovni interval. / Ni podatkov.

Information/Turtle name	**Rudica**	**Berta**	**Alta**	**Loredana**	**Nevija**
Id of telemetry tag	999001	999003	999004	999005	999006
Straight-line carapacial length (mm)	133.17	162.00	128.07	148.14	137.30
Body mass (g)	403	670	383	526	426
Age	4.class	4. class	3. class	5. class	4. class
Sex	Female	Female	Female	Female	Female
Eggs presence	yes	no	yes	no	no
Deployment date	11.06.2019	18.04.2019	11.06.2019	24.05.2019	26.05.2019
Last downloaded data	13.07.2019	04.06.2020	14.09.2019	18.06.2019	29.06.2020
Telemetry time interval	120*min	15 min	5 min	5 min	10 min
Number of locations	31	4038	832	256	3440
Number of locations in 2019	31	3419	832	256	1796
Number of locations in 2020	/	619	/	/	1644
Number of tracking days with data	18	193	36	12	155
Number of tracking days in 2019	18	129	36	12	61
Number of tracking days in 2020	/	64	/	/	94

Appendix 2: Characteristics of predictor covariates used for the habitat use analysis by the European Pond Turtle** (E. orbicularis) **in the Sečovlje Salina Nature Park. *Values of covariates where categories are listed were defined based on Jenks natural breaks (1 = very low. 2 = low. 3 = moderate. 4 = high. 5 = very high). **A) Slovenian Environment Agency (ARSO - Agencija RS za okolje), B) Slovenian Water Agency (DRSV), C) Ministry of Agriculture, Forestry and Food (MKGP), and D) Municipality of Piran.

Priloga 2: Značilnosti kovariat, uporabljenih pri analizi rabe habitata močvirske sklednice** (E. orbicularis) **v Krajinskem parku Sečoveljske soline. Vrednosti kovariat, kjer so podane kategorije, so bile določene z metodo Jenksovih naravnih prelomov (1 = zelo nizko; 2 = nizko; 3 = zmerno; 4 = visoko; 5 = zelo visoko).A) Agencija Republike Slovenije za okolje (ARSO), B) Direkcija Republike Slovenije za vode (DRSV), C) Ministrstvo za kmetijstvo, gozdarstvo in prehrano (MKGP) in D) Občina Piran.

Covariate		**Range or category***	**Description**	**Data source****
Topographical	**Aspect**	North: 337.5 - 22.5 Northeast: 22.5 - 67.5 East: 67.5 - 112.5 Southeast: 112.5 - 157.5 South: 157.5 - 202.5 Southwest: 202.5 - 247.5 West: 247.,5 - 292.5 Northwest: 292.5 - 337.5	Area [m^2] of aspect categories in each HR indicating the compass direction the surface faces at that location.	A)
	Slope [°]	1: 0.00 - 2.68 2: 2.684 - 7.77 3: 7.77 - 14.74 4: 14.749 - 24.39 5: 24.395 - 68.35	Area [m^2] of steepness of the slope categories in each HR.	A)
	Solar radiation [kwh/m^2]	1: 366.49 - 818.70 2: 818.71 - 949.34 3: 949.344 - 1,029.74 4: 1,029.74 - 1,096.73 5: 1,096.73 - 1,220.67	Area [m^2] of incoming solar radiation from a raster surface category in each HR.	A)
	Topographic Wetness Index (TWI)	1: 0.20 - 3.72 2: 3.72 - 5.03 3: 5.03 - 6.34 4: 6.34 - 8.00 5: 8.00 - 15.39	Area [m^2] of topographic wetness categories as an estimation of water accumulation locations in an area with elevation differences in each HR.	A)
	Terrain Ruggedness Index (TRI)	1: 0.00 - 0.12 2: 0.12 - 0.39 3: 0.39 - 0.77 4: 0.77 - 1.33 5: 1.33 - 6.16	Area [m^2] of terrain ruggedness categories as measure of the difference in elevation values from a center cell and eight cells directly surrounding it in each HR.	A)
	Vector Ruggedness Measure (VRM)	1: - 0.00 - 0.0007 2: 0.0007 - 0.003 3: 0.003 - 0.006 4: 0.006 - 0.01 5: 0.01 - 0.05	Area [m^2] of terrain ruggedness categories as the variation in 3-D orientation of grid cells within a neighborhood calculated in each HR.	A)
Environmental/ anthropogenic	**Waterway [m]**	0 - 839.89	Length of waterways in each HR.	B)
	Lentic water [m2]	0 - 40,088.71	Area [m^2] of waterways in each HR.	B)
	Lotic water [m2]	0 - 13,053.33	Area [m^2] of waterbodies in each HR.	B)
	Land use	1100 - Field 1190 - Greenhouse 1211 - Vineyard 1221 - Intensive orchard 1222 - Extensive orchard 1230 - Olive orchard 1300 - Meadow 1410 - Abandoned farm land 1500 - Trees 1600 - Uncultivated land 3000 - Urban land 4220 - Marsh 7000 - Water	Area of land use categories in each HR.	C)
	Cycling path [m]	0 - 237.24	Length of cycling paths in each HR.	D)

Appendix 3: The percentages/average values of the covariate categories/range during the entire study period (2019-2020) of the representative European Pond Turtle** (E. orbicularis) **in the Lera (turtle Berta) and in the Fontanigge (turtle Nevija) in the Sečovlje Salina Nature Park. n = number of locations assigned to environmental/anthropogenic or topographical covariate range/category. *Pearson Chi-Square/Mann Whitney. / No data

Priloga 3: Odstotki/povprečne vrednosti kategorij/razponov kovariat v celotnem obdobju raziskave (2019–2020) za izbrani samici močvirske sklednice** (E. orbicularis) **na območju Lere (želva Berta) in Fontanigg (želva Nevija) v Krajinskem parku Sečoveljske soline. n = število lokacij, dodeljenih posameznim okoljskim, antropogenim ali topografskim razponom oziroma kategorijam kovariat. Pearsonov hi-kvadratni test/Mann-Whitneyjev test. / Ni podatkov.

Covariate	**Lera**				**Fontanigge**			
	2019-2020	**n**	**Statistics***	**Significance (p)**	**2019-2020**	**n**	**Statistics***	**Significance (p)**
% of Land use category								
Field	9.41	380	1273.464	< 0.001	0.00	0	1395.361	< 0.001
Vineyard	0.20	8			0.00	0		
Meadow	0.47	19			0.00	0		
Abandoned farm land	0.02	1			0.06	2		
Trees	0.02	1			0.00	0		
Uncultivated land	10.75	434			0.00	0		
Urban land	11.22	453			90.50	3113		
Marsh	54.93	2218			0.73	25		
Water	12.98	524			8.71	300		
% of all locations								
Lentic water	18.20	64	109.342	< 0.001	3.80	132	368.645	< 0.001
Lotic water	64.60	736	843.248	< 0.001	74.20	2550	99.223	< 0.001
Waterway	1.60	2600	75.040	< 0.001	4.60	158	5.718	0.456
Cycling path	0.99	35	16.527	0.021	/	0	/	/
% of Aspect range								
East	13.22	534	260.360	< 0.001	10.74	368	110.982	< 0.001
North	8.59	347			6.09	210		
Northeast	9.91	400			13.78	474		
Northwest	21.47	867			7.92	272		
South	5.94	240			8.18	281		
Southeast	18.13	732			8.39	289		
Southwest	8.30	335			28.32	975		
West	14.44	583			16.57	571		
Mean value								
Slope (°)	Low (3.90)	4038	312.997	< 0.001	Very low (2.63)	3440	99.89	< 0.001
Solar radiation (kwh/m^2)	High (1053.21)	4038	49.594	< 0.001	High (1063.89)	3440	32.634	< 0.001
Topographic Wetness Index	Low (4.59)	4038	117.898	< 0.001	Low (4.88)	3440	75.57	< 0.001
Terrain Ruggedness Index	Low (0.180)	4038	348.054	< 0.001	Low (0.122)	3440	107.95	< 0.001
Vector Ruggedness Measure	Low (0.00055)	4038	329.952	< 0.001	Very low (0.00029)	3440	76.425	< 0.001

HABITATNE ZNAČILNOSTI MOČVIRSKE SKLEDNICE (*EMYS ORBICULARIS*) V KRAJINSKEM PARKU SEČOVELJSKE SOLINE, SLOVENIJA

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POVZETEK

*V Krajinskem parku Sečoveljske soline (KPSS), enem največjih obalnih somornih mokrišč v Sloveniji, smo izvedli obsežno raziskavo habitatnih zahtev (območje razširjenosti, premike in rabo habitata) sladkovodne vrste želve močvirske sklednice (*Emys orbicularis*). V letih 2019- 2020 smo opremili pet samic z GPS-oddajniki na sončno energijo. Z uporabo visoko-ločljivih LiDAR podatkov ter podrobne prostorske analize smo primerjali aktivnosti posameznih želv na mesečni ravni in v času hibernacije, in sicer na dveh ekološko različnih sosednjih območjih znotraj parka, kjer je vrsta prisotna v največjem številu. Podatki, zbrani v tako kratkem (mesečnem) obdobju, zagotavljajo dragocen vpogled v habitatne zahteve, sezonsko dinamiko rabe prostora ter razlike v okoljskih razmerah. Rezultati predstavljajo pomembno izhodišče za oblikovanje ciljno usmerjenih naravovarstvenih ukrepov za ohranjanje te ogrožene vrste želve v obalnih somornih mokriščih, ki so pogosto krajevno specifična in izpostavljena številnim vplivom človeka.*

Ključne besede: Močvirska sklednica, *Emys orbicularis hellenica*, GPS-telemetrija, LiDAR, raba habitata, naravovarstveni ukrepi, obalno mokrišče

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NAJDBE PLEISTOCENSKE AVIFAVNE V KAMNOLOMU ČRNI KAL (PRIMORSKA, SLOVENIJA)

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IZVLEČEK

*V članku prvič predstavljamo najdbe fosilnih ostankov ptic, nabranih med leti 1996 in 2002 na najdišču 1/II v kamnolomu Črni Kal v Slovenski Istri. Fosilni material obsega 94 kostnih ostankov ptic, ki jih je preliminarno določila Vesna Malez, njene določitve pa smo še dodatno pregledali in dopolnili. Skupno smo prepoznali 24 taksonov, od katerih je bilo 21 določenih do vrste natančno. Med najdbami prevladujejo pevke (Passeriformes), zlasti planinska vrana (*Pyrrhocorax pyrrhocorax*). Glede na habitatno preferenco vrstam odprtih habitatov pripada 61% vseh določenih primerkov (NISP), medtem ko je delež gozdnih vrst le 13%. Na podlagi vrstne sestave je v prispevku rekonstruirano takratno paleookolje na širšem območju črnokalskega najdišča 1/II. Ker gre za vrstno najbogatejše pleistocensko najdišče ptic na območju Slovenije, je objava seznama pomemben prispevek k poznavanju pleistocenske avifavne tega prostora.*

Ključne besede: Črni Kal, fosilne najdbe, ptice, avifavna, pleistocen, paleookolje

RITROVAMENTI DI AVIFAUNA PLEISTOCENICA NELLA CAVA DI ČRNI KAL (PRIMORSKA, SLOVENIA)

SINTESI

*Gli autori presentano per la prima volta i ritrovamenti di resti fossili di uccelli, raccolti tra il 1996 e il 2002 nel sito 1/II della cava di Črni Kal, nell'Istria slovena. Il materiale fossile comprende 94 resti ossei di uccelli, già determinati da Vesna Malez e ulteriormente riesaminati. Sono stati riconosciuti 24 taxa, di cui 21 identificati con precisione a livello di specie. Tra i ritrovamenti predominano i passeriformi (Passeriformes), in particolare il gracchio corallino (*Pyrrhocorax pyrrhocorax*). In base alle preferenze di habitat, il 61% di tutti gli esemplari determinati appartiene a specie di ambienti aperti, mentre la quota di specie forestali è solo del 13%. Nell'articolo viene ricostruito il paleoambiente dell'epoca nell'area più ampia del sito di Črni Kal 1/II. Poiché si tratta del sito pleistocenico di uccelli più ricco in termini di specie nell'area della Slovenia, la pubblicazione dell'elenco rappresenta un importante contributo alla conoscenza dell'avifauna pleistocenica di questa regione.*

Parole chiave: Črni Kal, ritrovamenti fossili, uccelli, avifauna, Pleistocene, paleoambiente

UVOD

Kamnolom Črni Kal se nahaja v neposredni bližini regionalne ceste Ljubljana – Koper približno 500 metrov severno od naselja Črni Kal v Slovenski Istri. Območje, na katerem leži kamnolom, predstavljajo predvsem močno zakraseli eocenski alveolinsko-numulitni apnenci (Križnar & Preisinger, 2017). S širitvijo kamnoloma so se v preteklih desetletjih odpirale številne s pleistocenskimi sedimenti zasute jame in brezna, v nekaterih izmed njih pa so s paleontološkimi pregledi in delno arheološkimi izkopavanji odkrili številne ostanke pleistocenske favne (Polak *et al.*, 2023 in tam navedena literatura).

Pozornost pri popisovanju najdb in njihovi interpretaciji je bila tradicionalno skoraj izključno namenjena fosilnim najdbam večjih sesalcev. Te so bile že v prvih objavah o izkopavanjih v kamnolomu Črni Kal izčrpno opisane in jih navajamo v kratkem pregledu v nadaljevanju (Brodar, 1958; Rakovec, 1958). Z novimi izkopavanji se je poznavanje prisotnosti pleistocenskih sesalcev na tem območju večkrat še dopolnjevalo (Pavlovec & Pohar, 1997; Aguilar *et al.*, 1998; Jamnik *et al.*, 2013; Križnar & Preisinger, 2017; Polak *et al.*, 2023), vendar časovna opredelitev najdb še vedno ni v celoti pojasnjena (Brodar, 2009).

Fosilnim ostankom ptic v okviru raziskav črnokalskega favnističnega gradiva ni bila posvečena večja pozornost, čeprav so bili ti najdeni na dveh najdiščih znotraj kamnoloma. Leta 1958 najdbe ptičjih kosti navaja Srečko Brodar, pozneje pa je bilo večje število ptičjih kosti odkrito še na novejšem najdišču (najdišče 1/II, povzeto po Jamnik *et al.*, 2013; Križnar & Preisinger, 2017). Za nobeno izmed najdišč vrste najdenih ptic niso bile objavljene.

Tudi sicer so tako v Sloveniji, kot tudi v evropskem merilu, fosilne najdbe ptic pri proučevanju arheoloških in paleontoloških najdišč običajno močno zapostavljene (Tyrberg, 1998). V Sloveniji se je v preteklosti bolj sistematičnega popisa in interpretacije pleistocenskih fosilnih najdb ptic lotila le hrvaška paleontologinja Vesna Malez (Malez, 1995; 1997; 2007),, sicer pa se ostali avtorji paleontoloških raziskav s pticami niso ciljno ukvarjali in so njihove morebitne najdbe običajno obravnavali le postransko (Pohar, 1983; Tyrberg, 1998; Jamnik *et al.*, 2013; Jamnik *et al.*, 2021; Jamnik *et al.*, 2022).

Poznavanje pleistocenske avifavne na območju današnje Slovenije je tako še vedno zelo skromno. Pričujoča objava avifavne iz Črnega Kala zato pomembno prispeva k napredku na tem področju in pomeni korak naprej pri vključevanju ptic v paleookoljske študije in raziskave.

Zgodovinski pregled paleontoloških raziskav v kamnolomu Črni Kal

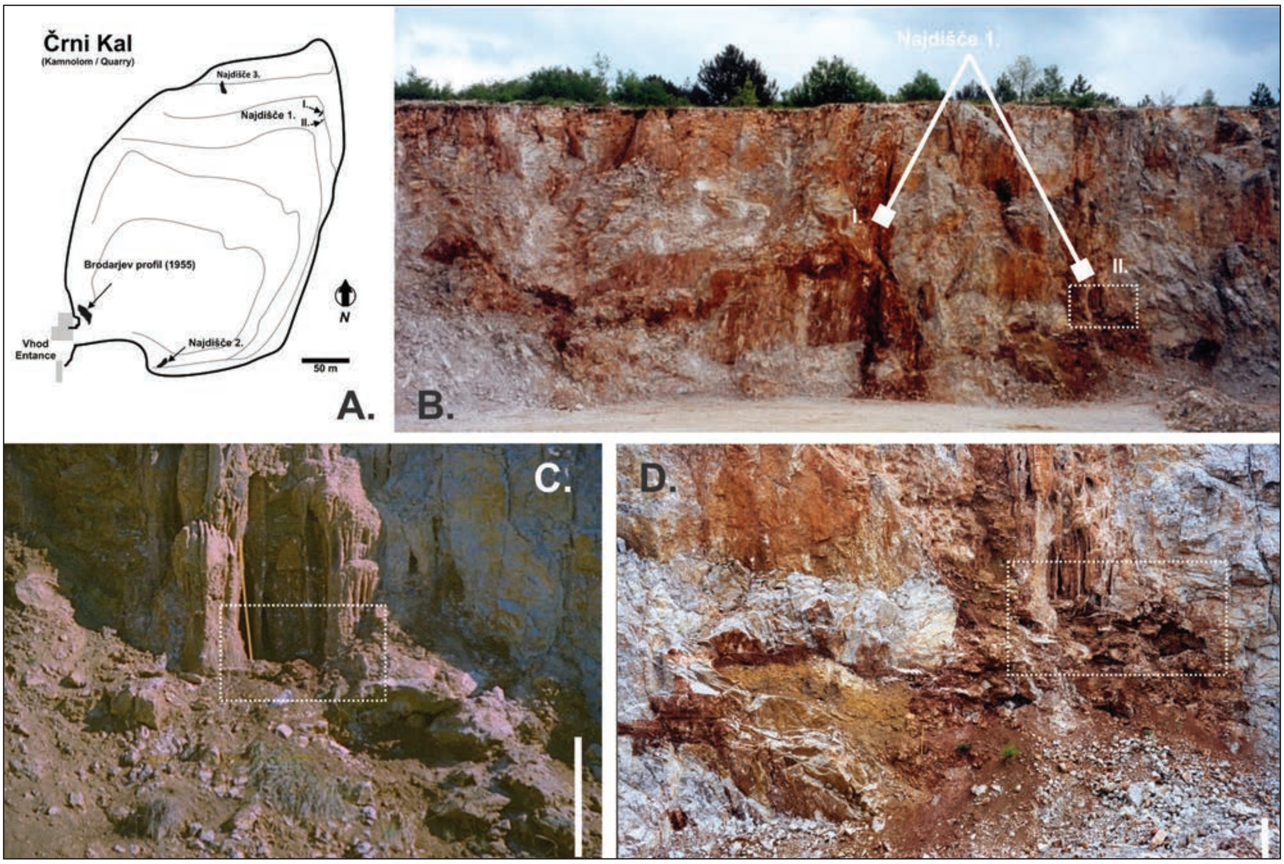
Prve arheološko-paleontološke raziskave so v kamnolomu Črni Kal stekle že leta 1955, ko je bila kot posledica širitve kamnoloma odkrita s sedimenti zasuta jama s številnimi ostanki pleistocenske favne (Brodar, 1958; Rakovec, 1958). Med izkopavanji pod vodstvom Srečka Brodarja so prepoznali stratigrafsko sosledje 20 plasti, pri čemer je najnižja pripisana mindelsko-riški medledeni dobi, kronologija najvišjih plasti, pripisanih würmu, pa še ni pojasnjena (Brodar, 1958; 2009).

Zbrano paleontološko gradivo vključuje ostanke jamskega medveda (*Ursus spelaeus*), v manjšem številu pa še ostanke nekaterih drugih večjih sesalcev (Rakovec, 1958; glej tudi Jamnik *et al.*, 2013). Nekaj malih sesalcev je bilo odkritih le po izpiranju vzorcev posameznih plasti, v plasteh 4 in 5 pa je bilo odkritih nekaj manjših ptičjih kosti (Brodar, 1958; Rakovec, 1958: 280, 281). Človekova prisotnost je bila nedvomno potrjena z najdbo musterjenskega kotnega strgala v plasti 10 (Brodar, 1958; Brodar, 2009; Jamnik *et al.*, 2013: 16). Leta 2009 je bil najden še klaktonjenski odbitek, ki so ga pripisali 13. plasti, nakazuje pa na to, da je jamo človek obiskoval v vsaj dveh različnih obdobjih (Jamnik *et al.*, 2013: 15).

Leta 1955 raziskani Brodarjev profil se nahaja na južnem delu današnjega obsega kamnoloma (Sl. 1) in je danes ohranjen le v manjšem obsegu. Tu je pozneje Miha Krofel z dodatnimi izkopavanji še razširil seznam popisanih vrst, ki sicer zajema predvsem velike sesalce, ponovno pa za to najdišče navaja tudi ostanke ptic, toda brez natančnih taksonomskih določitev (Polak *et al.*, 2023; Polak & Krofel, ustni vir).

S širitvijo kamnoloma proti severu in vzhodu so se pogosto odpirala manjša brezna in erozijsko razširjene in zapolnjene razpoke (Jamnik *et al.*, 2013). Dve takšni razpoki na takratnem severnem robu kamnoloma sta bili delno zapolnjeni s pleistocenskimi sedimenti, iz katerih je bilo ob več obiskih v letih 1996 – 2002 zbrano večje število ostankov vretenčarjev (Jamnik *et al.*, 2013). V skladu s poimenovanji najdišč v kamnolomu Črni Kal, ki jih uporabljajo Jamnik in sod. (2013, Sl. 8) navajamo to najdišče kot najdišče 1 (Sl. 1).

Pavlovec in Pohar (1997) za najdišče 1 omenjata najdbo rebra, ki naj bi pripadalo nosorogu in na katerem naj bi bili vidni vrezi človeškega izvora, kar pa zavračajo Jamnik in sodelavci (2013). Med velikimi sesalci Jamnik in sod. (2013) navajajo predvsem najdbe jelenov (*Cervus* cf. *elaphus*) in srn (*Capreolus* sp.), sicer pa še ostanke goveda (*Bos* sp. seu *Bison* sp.), nosorogov (*Stephanorhinus* cf. *kirchbergensis* in *Stephanorhinus* cf. *hemitoechus*), lisic



Sl. 1: Shema kamnoloma pri Črnem Kalu leta 2017 in lege pleistocenskih najdišč (prirejeno po Jamnik* et al.*, 2013; Križnar & Preisinger, 2017) (A). Fotografija stanja najdišč 1/I in 1/II leta 2001 (B). Situacija najdišča 1/II leta 1997 (C) in leta 2001 (D), ko je bil del najdišča že uničen in delno odstranjen. S pravokotnikom je označeno najdišče tukaj predstavljene pleistocenske avifavne. Foto: Matija Križnar

Fig. 1: Schematic map of the Črni Kal quarry in 2017 and the positions of Pleistocene sites (modified after Jamnik* et al.*, 2013; Križnar & Preisinger 2017) (A). Photograph of the state of sites 1/I and 1/II in 2001 (B). Situation of site 1/II in 1997 (C) and in 2001 (D), when part of the site had already been destroyed and partly removed. The rectangle marks the site of the Pleistocene avifauna presented in this study. Photo: Matija Križnar.

(*Vulpes* sp.), kun (*Mustela* cf. *putorius*) in verjetno meljak deningerijevega medveda (*Ursus* cf. *deningeri*). Najdbe mnogih ostankov ptic Jamnik in sodelavci (2013) le omenijo in med njimi izpostavijo vrane (družina Corvidae) in koconoge kure (družina Tetraonidae), ne podajo pa seznama posameznih odkritih vrst. Prav tako le omenijo najdbe malih sesalcev, ki pa so jih iz treh najdišč v črnokalskem kamnolomu podrobneje opisali že Aguilar in sod. (1998). Za najdišče 1, ki ga sami označijo kot Črni Kal 3 (Jamnik *et al.*, 2013), omenjajo največ vrst glodavcev (Rodentia), prisotni pa so še žužkojedi (Insectivora) in netopirji (Chiroptera) (Aguilar *et al.*, 1998). Najdišče 1 (po Polak *et al.*, 2023 je to najdišče 3, oziroma 3a in 3b) je neodvisno obiskoval tudi Miha Krofel, ki navaja najdbe divje mačke (*Felis silvestris*) in mosbaškega volka (*Canis mosbachensis*), omenja pa še možno prisotnost rdečega oz. alpskega volka (*Cuon*), ene od lisic (*Vulpes* ali *Alopex*), male podlasice (*Mustela nivalis*), tura (*Bos primigenius*), kozoroga (*Capra ibex*) in zajca (*Lepus* sp.) (Polak *et al.*, 2023).

Edini poizkus časovne umestitve najdišča 1 ni povsem jasen. Pavlovec in Pohar (1997) iz tega najdišča navajata radiokarbonsko datiranje (^{14}C) kosti nosoroga, ki je pokazalo datacijo starejšo od 45.000 let, kar je mejna vrednost omenjene datacijske metode. Aguilar in sod. (1998) iz kamnoloma Črni Kal govorijo o datiranju neopredeljenih najdišč v zgodnji in srednji pleistocen, Mihevc (2001) pa je vzorec sige iz brezna (ob cestnem vseku) pri kamnolomu Črni Kal datiral na 143.000 let.

Poleg Brodarjevega najdišča in najdišča 1, ki sta s paleontološkimi najdbami najbolj bogati, sta bili pozneje s širjenjem kamnoloma odkriti še dve najdišči (Sl. 1 – najdišče 2 in najdišče 3, povzeto po Jamnik *et* *al*., 2013). Na najdišču 2 na jugu kamnoloma so v breznu v zapolnitvi z rdečkasto ilovico odkrili več slabo ohranjenih kostnih ostankov sesalcev, med katerimi so določili zobe pleistocenskega nosoroga (Jamnik *et al*., 2013). Najnovejša odkritja ostankov velikih sesalcev z najdišča 2 so pozneje opisali še Polak in sod. (2023), ki pa to najdišče navajajo kot najdišče 4.

Leta 2016 je bilo raziskano še na novo odprto najdišče 3 na severozahodni strani kamnoloma Črni Kal. Ponovno gre za brezno, ki je bilo v celoti zapolnjeno z različnimi sedimenti, najdbe fosilnih ostankov iz plasti kostne breče pa so bile do sedaj objavljene le preliminarno, med njimi pa prevladujejo ostanki jelenov (Križnar & Preisinger, 2017). Istočasno a povsem neodvisno so poleg Križnarja in Preisingerja najdišče 3 obiskovali tudi Polak, Hitij in Josipovič, ki najdišče označijo (preštevilčijo) s številko 5. Med popisanimi najdbami sesalcev je najbolj zanimiva najdba zoba makaka (*Macaca sylvanus*) (Polak *et al*. 2023). Starost najdišča so Polak in sodelavci (2023) ocenili na prehod iz poznega zgodnjega pleistocena v srednji pleistocen oziroma na približno 700.000 do 800.000 let pred sedanjostjo.

MATERIAL IN METODE

Leta 1996 sta se zaradi širjenja kamnoloma in razstreljevanja na severnem delu kamnoloma odprli dve razpoki, ki sta bili delno zapolnjeni s pleistocenskimi sedimenti (ilovica, breča in sigaste tvorbe). Na podlagi sigastih oblog in kapnikov sta zapolnjeni razpoki nastali in v preteklosti najverjetneje delovali kot ozka kraška brezna. Večji del teh sedimentnih zapolnitev je bil zaradi hitrega napredovanja in obratovanja kamnoloma uničen in odpeljan še preden je bilo mogoče izvesti temeljitejša paleontološka izkopavanja (Jamnik *et al*., 2013). Kljub temu je bilo ob več obiskih v letih od 1996 do 2002 nabrano večje število ostankov pleistocenskih sesalcev, ki so jih delno predstavili že Jamnik in sodelavci (2013), dvojno najdišče pa so opisali kot najdišči 1/I in 1/II. V tem obdobju je bilo na najdišču 1/II nabranih tudi 94 fosiliziranih ptičjih kosti. Podrobne podatke o teh najdbah v tem članku navajamo prvič.

Nabiranje omenjenih ptičjih kosti ni potekalo sistematično, nabrane so bile na razkritem delu najdišča brez stratigrafske opredelitve na območju označenem na sliki 1 (glej Sl. 1 C, D). Večji del zbranega avifavnističnega gradiva je bil pobran na policah med sigastimi tvorbami. Mnoge od kosti so bile prekrite s tanko sigasto (kalcitno) prevleko. Determinacijo ptičjih kosti je preliminarno opravila Vesna Malez iz Zavoda za paleontologijo in geologijo kvartarja Hrvaške akademije znanosti in umetnosti, pri čemer se je naslonila na tamkajšnjo primerjalno osteološko zbirko recentnih ptic.

Najdbe ptic z najdišča 1/II, ki jih danes hrani Prirodoslovni muzej Slovenije, smo tudi sami pregledali in dopolnili. Velika večina predhodnih določitev je bila zanesljiva, pri nekaterih pa so bili potrebni taksonomski popravki. Pri pregledu določitev smo si pomagali z osteomorfometrično literaturo (Erbersdobler, 1968; Cohen & Serjeantson, 1996; Tomek & Bochenski, 2000) in z osteološko zbirko ptic, ki jo hrani Prirodoslovni muzej Slovenije.

Poskusili smo pridobiti tudi ptičje kosti, ki jih med najdbami v plasteh 4 in 5 na Brodarjevem najdišču omenja Srečko Brodar (1958) in najdbe ptičjih kosti Mihe Krofla, ki jih med najdbami na ostanku Brodarjevega najdišča omenjajo Polak in sod. (2023). Te najdbe smo želeli ustrezno popisati in determinirati prisotne vrste, vendar nam doslej še ni natančno uspelo izvedeti, kje so shranjene.

Za vsako vrsto je bilo določeno število najdenih posameznih kostnih elementov in opisano njihovo stanje. Na podlagi zbranih podatkov smo izračunali skupna števila določenih primerkov (NISP – ang. number of identified specimens), ki smo jih uporabili za okvirno primerjavo relativnih frekvenc posameznih vrst oziroma taksonov (Reitz & Wing, 2008). Ker se pri raziskavi osredotočamo le na primerjave najdb ptic, ki so osteološko dovolj homogena skupina, smo ocenili, da izračun in uporaba najmanjšega števila osebkov (MNI – ang. minimum number of individuals) ni smotrna (Reitz & Wing, 2008). Pri poimenovanju posameznih kostnih elementov smo uporabili terminologijo in okrajšave v skladu z objavami Janžekoviča in sod. (2005, 2015).

Za izračun razmerja med številom najdb dolgih kosti sprednje okončine (oziroma krila) in številom najdb dolgih kosti zadnje okončine (oziroma noge) so bile kot kosti krila uporabljene humerus, ulna in karpometakarpus, kot kosti noge pa femur, tibia in tarzometatarzus (Bochenski & Nekrasov, 2001). Pri izračunu razmerja med številom najdb proksimalnih in distalnih kosti skeleta so bile kot proksimalne kosti uporabljene skapula, korakoid, humerus in femur, kot distalne kosti pa ulna, radius, karpometakarpus in tarzometatarzus (Bochenski & Nekrasov, 2001).

Ekološka interpretacija najdb in rekonstrukcija paleookolja temeljita na poznavanju ekoloških potreb in habitatnih preferenc sodobnih populacij proučevanih vrst. Pri kategorizaciji posameznih vrst glede na njihovo habitatno preferenco smo sledili primerom iz drugih strokovnih objav (Finlayson, 2011; Holm & Svenning, 2014). Najdenim vrstam je bil tako pripisan odprt, mešan ali gozdni habitat, posebej pa smo poleg kategorije odprt habitat ločili še tundro, kamor smo uvrstili najdbo *Lagopus* sp. (Finlayson, 2011). Sodobno razširjenost posameznih vrst in njihovo morebitno lokalno prisotnost na območju Črnega Kala oziroma slovenske Istre smo ugotovili na podlagi Atlasa ptic Slovenije (Mihelič *et al*., 2019).

REZULTATI

Na podlagi oblike kosti smo določitve Vesne Malez v dveh primerih koreniteje popravili: tarzometatarzus srake (*Pica pica*) je bil sprva napačno določen kot gozdni jereb (*Tetrastes bonasia*), femur prepelice (*Coturnix coturnix*) pa je bil napačno določen kot sraka (*Pica pica*). Glede na obliko kosti in morfometrične podatke smo popravili še napačno določitev tarzometatarzusa ruševca (*Lyrurus tetrix*) v divjega petelina (*Tetrao urogallus*), korakoida planinske vrane (*Pyrrhocorax pyrrhocorax*) v srako (*Pica pica*) in tarzometatarzusa kanje (*Buteo buteo*) v rod lunjev (*Circus* sp.). Slednjega zaradi pomanjkljive zbirke Prirodoslovnega muzeja Slovenije ni bilo mogoče natančneje določiti. Na podlagi primerjalnih morfometričnih podatkov smo do vrste določili še štiri kostne elemente, ki so bili prej določeni le kot *Pyrrhocorax* sp. ali *Corvus* sp. (Tomek & Bochenski, 2000). Dodatno so bile določene še tri skapule, ki jih Vesna Malez ni predhodno določila.

Najdišče 1/II v kamnolomu Črni Kal je kljub temu, da je bil večji del najdišča uničen, fosilni ostanki ptic pa niso bili nabrani sistematično, zaenkrat vrstno najbolj pestro najdišče pleistocenskih ptic v Sloveniji. Med 92 določenimi kostnimi najdbami ptic je bilo določenih 21 različnih vrst, štirje primerki pa so bili taksonomsko opredeljeni le do rodu (Tab. 1). Pri dveh fragmentiranih kosteh smo lahko prepoznali le, da gre za kosti ptic.

Tab. 1: Seznam prepoznanih taksonov ptic s pripisanim številom najdenih posameznih kostnih elementov in s skupnim NISP. Okrajšave kostnih elementov: C – korakoid, Sc – skapula, H – humerus, U – ulna, R – radius, CM – karpometakarpus, F – femur, TI – tibiotarzus. TM – tarzometatarzus, Ph – prstnica.
Tab. 1: List of bird taxa with the number of identified skeletal elements and the total NISP. Abbreviations of skeletal elements: C – coracoid, Sc – scapula, H – humerus, U – ulna, R – radius, CM – carpometacarpus, F – femur, TI – tibiotarsus, TM – tarsometatarsus, Ph – phalanx.

Vrsta	**C**	**Sc**	**H**	**U**	**R**	**CM**	**F**	**TI**	**TM**	**Ph**	**NISP**
Tetrastes bonasia	1										1
Lagopus sp.						1					1
Tetrao urogallus									1		1
Lyrurus tetrix									2		2
Coturnix coturnix			1	1		2	2		1		7
Circus sp.									1		1
Buteo buteo	1										1
Falco tinnunculus							1	1		1	3
Falco subbuteo									2		2
Lanius excubitor	1										1
Pica pica	1	3					1				5
Nucifraga caryocatactes	1		1								2
Pyrrhocorax pyrrhocorax	2		2	5		6	2	3	5	2	27
Pyrrhocorax graculus	1		3					1			5
Pyrrhocorax sp.			2						3		5
Coloeus monedula							5	4			9
Corvus corax				1							1
Corvus sp.	1			4		2	1		1		9
Hirundo rustica								1			1
Sylvia borin								1			1
Sturnus vulgaris				1							1
Turdus viscivorus								3			3
Turdus merula	1										1
Fringila coelebs	1										1
Loxia curvirostra	1										1
Aves indet.							1		1		2
SUM (seštevek)	12	3	9	12	0	11	12	14	18	3	94

Tab. 2: Število določenih primerkov (NISP) po redovih in družinah ptic.
Tab. 2: Number of identified specimens (NISP) by orders and families of birds.

red	družina	NISP
GALLIFORMES	Phasianidae	12
ACCIPITRIFORMES	Accipitridae	2
FALCONIFORMES	Falconidae	5
PASSERIFORMES	Laniidae	1
	Corvidae	63
	Hirundinidae	1
	Sylviidae	1
	Sturnidae	1
	Turdidae	4
	Fringillidae	2

Najpogosteje zastopan red med najdbami so bile pevke (Passeriformes) z 71 določenimi primerki, od katerih pa je velika večina najdb pripisana družini vranov (Corvidae), predvsem rodu *Pyrrhocorax* (Tab. 1 in Tab. 2). Od drugih redov so med najdbami prisotni še predstavniki kur (Galliformes), ujed (Accipitriformes) in sokolov (Falconiformes). Glede na habitatno preferenco med najdbami prevladujejo fosilni ostanki vrst značilnih za odprte habitate, in sicer v deležu kar 61 %. Delež najdb fosilnih ostankov gozdnih vrst ptic je nizek – le 13 % (Tab. 3).

Po zastopanosti posameznih kostnih ostankov v analiziranem gradivu izstopajo tarzometatarzusi (18 primerkov), ostale dolge kosti pa so, z izjemo radiusa, med najdbami zastopane približno enakovredno (od 9 do 14 primerkov). Najdene in določene so bile še tri skapule in tri prstnice. Aksialni elementi, ki so pri pticah tudi na splošno na najdiščih redko prisotni, na najdišču 1/II niso bili najdeni.

Izračun razmerja med številom najdb kosti krila in kosti noge, je pokazal večjo prisotnost kosti noge (58%) v primerjavi s kostmi krila (42%). Pri razmerju med številom najdb proksimalnih in distalnih kosti, pa je razlika manjša in v prid distalnim kostem (47 : 53).

Na črnokalskem najdišču 1/II je bilo med pleistocenskimi najdbami za območje Slovenije prvič opisanih sedem vrst ptic: gozdni jereb (*Tetrastes bonasia*), prepelica (*Coturnix coturnix*), sraka (*Pica pica*), kavka (*Coloeus monedula*), kmečka lastovka (*Hirundo rustica*), vrtna penica (*Sylvia borin*) in mali krivokljun (*Loxia curvirostra*) (Cimerman, 2024).

Tab. 3: Deleži določenih elementov (delež NISP) glede na habitatno preferenco vrste, kateri so bili pripisani.
Tab. 3: Proportion of identified elements (NISP share) according to the habitat preference of the species to which they were assigned.

	delež NISP (%)
tundra	1
odprti habitat	61
mešani habitat	25
gozd	13

RAZPRAVA

Na širšem, ekološko primerljivem območju v okolici Črnega Kala, ki poleg slovenske Istre in primorskega zaledja zajema še hrvaško Istro in italijansko priobalno območje Tržaškega zaliva, so bile vse izmed najdenih vrst ptic na črnokalskem najdišču 1/II že opisane na vsaj enem izmed sosednjih pleistocenskih najdišč (Sl. 2), predvsem po zaslugi izjemno bogatih najdiščih fosilne favne Šandalja I in Šandalja II pri Puli, ki pa sta časovno sicer omejeni le na višek zadnje poledenitve (Tyrberg, 1998; Lenardić *et al.*, 2017). Večje število vrst ptic je bilo odkrito še na najdiščih na istrskem polotoku Marlera pri Medulinu in v jami Divje babe I iz obdobja pleniglaciala ter na najdišču Romualdova pećina z viška zadnje poledenitve (Malez, 2007; Lenardić *et al.*, 2017).

Tafonomija

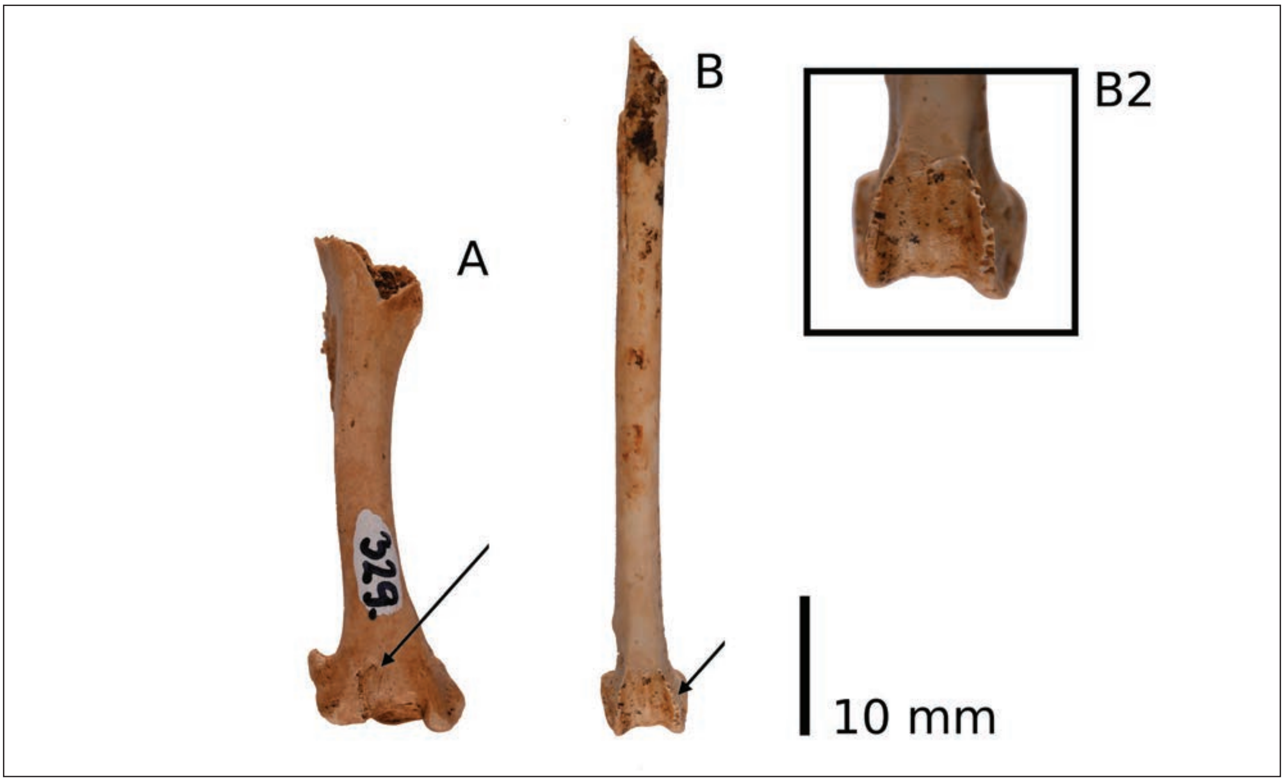
Na nobeni izmed kosti, ni bilo zaslediti ureznin, ki bi nakazovale, da gre za ostanke hrane človeka. Temu pritrjuje tudi bistveno večje število tarzometatarzusov med najdbami v primerjavi s femurji. Za ostanke hrane človeka je namreč značilna večja prisotnost kosti bogatih z mesom, kot sta humerus in femur, medtem ko so kosti kot sta karpometakarpus in tarzometatarzus, značilne za izbljuvke ujed in sov ter se pogosto akumulirajo na njihovih gnezdiščih in prehranjevališčih (Baales, 1992; Bochenski *et al.*, 2018; Lloveras *et al.*, 2018; Nunez-Lahuerta *et al.*, 2024). Za izbljuvke ujed in sov so razmerja med številom posameznih skupin kostnih elementov v izbljuvkih vrstno specifična in sodeč po študiji Bochenskega in Nekrasovega (2001), je kraljevi orel (*Aquila heliaca*) edina vrsta, pri kateri je razmerje med kostmi krila in kostmi noge v izbljuvkih obrnjeno v prid kostem noge. To se ujema z razmerjem, ki je bilo ugotovljeno za najdbe kosti na najdišču 1/II, nadalje pa se s podatki za kraljevega orla ujema tudi razmerje med številom najdb proksimalnih in distalnih kosti na najdišču 1/II, saj je kraljevi orel poleg arktičnega sokola (*Falco rusticolus*) edina vrsta z uravnoteženim razmerjem, medtem ko so

Sl. 2: Zemljevid lokacij pleistocenskih najdišč v širši okolici Črnega Kala, na katerih so bile popisane najdbe ptic.
Fig. 2: Map of Pleistocene sites in the wider area around Črni Kal where bird finds have been recorded.

pri drugih vrstah proksimalne kosti vedno zastopane v občutno večjem deležu (Bochenski & Nekrasov, 2001).

Možnost, da gre za izbljuvke kraljevega orla je podprta tudi z ekologijo te vrste. Danes kraljevi orel sicer na območju Slovenije ni prisoten, temveč njegov areal v Evropi predstavljajo vzhod Panonske nižine, deli Balkanskega polotoka in nižine vzhodne Evrope. Gre torej za vrsto nižinskih odprtih habitatov s posameznimi drevesi in manjšimi gozdovi (Gonzalez, 2007; Demerdzhiev *et al.*, 2022). Tak habitat je v hladnih obdobjih pleistocena obsegal večji del Evrope in upravičeno je sklepati, da je bil areal kraljevega orla v tem obdobju razširjen tudi proti zahodu, kar potrjujejo tudi najdbe na zahodnem Madžarskem in v Švici (Tyrberg, 1998), ter ostanki disjunktne podvrste v Španiji (Gonzalez, 2007).

Da so bile najdene kosti na najdišču najverjetneje posledica izbljuvkov nakazujejo tudi značilne poškodbe, ki nastanejo kot posledica kljuvanja in prebave na nekaterih izmed najdenih kosti (Sl. 3) (Lloveras *et al.*, 2018). Hkrati pa ne moremo izključiti, da je del najdb na najdišču lahko tudi posledica naravne smrti ptic. V primeru rodu *Pyrrhocorax*, ki je med najdbami najpogosteje zastopan, gre za najdbe kosti planinske vrane (*Pyrrhocorax pyrrhocorax*) in planinske kavke (*Pyrrhocorax graculus*), torej za vrsti, ki gnezdita v skalnih stenah in celo v kraških jamah (Mihelič *et al.*, 2019), zato je zelo verjetno, da so bile razpoke pri vhodu v jamo najdišča 1/II uporabljene tudi kot gnezdišča (Laroulandie, 2010; Lloveras *et al.*, 2018). Na gnezdenje nakazujejo tudi najdbe kosti med drugim pripisane tudi rodu *Pyrrhocorax*, ki niso dokončno osificirane in



Sl. 3: Poškodba nastala kot posledica kljuvanja na najdbi humerusa krekovta** (Nucifraga caryocatactes) **(A) in poškodba nastala kot posledica prebave na najdbi tibiotarzusa planinske vrane** (Pyrrhocorax pyrrhocorax) **(B in B2).
Fig. 3: Damage caused by pecking observed on a humerus of Northern nutcracker** (Nucifraga caryocatactes) **(A), and damage caused by digestion observed on a tibiotarsus of Red-billed chough** (Pyrrhocorax pyrrhocorax) **(B and B2).

Sl. 4: Primeri ne-povsem osificiranih kosti juvenilnih osebkov: najdba tarzometatarzusa ruševca** (Lyrurus tetrix) **(A) in najdba humerusa planinske kavke** (Pyrrhocorax graculus) **(B).
Fig. 4: Examples of incompletely ossified bones of juvenile individuals: a tarsometatarsus of Black grouse** (Lyrurus tetrix) **(A) and a humerus of Alpine chough** (Pyrrhocorax graculus) **(B).

so torej pripadale juvenilnim osebkom (Sl. 4). Luknje v ostenjih, včasih pa tudi kraške jame, so bila naravna gnezdišča tudi kavkam (*Coloeus monedula*), preden so se te preselile v urbana okolja (Mihelič *et al.*, 2019).

Ekološka interpretacija in rekonstrukcija paleookolja

Glede na habitatno preferenco med najdbami prevladujejo fosilni ostanki vrst, ki so značilne za odprte habitate, in sicer v deležu kar 61% (Tab. 3). Med njimi je številčno najbolj prisotna planinska vrana (*Pyrrhocorax pyrrhocorax*), torej tipična vrsta območij z nizko vegetacijo, ki danes poseljuje gorske travnike in skalnata območja, na območju Slovenije pa ni več prisotna (Cramp *et al.*, 1994; Mihelič *et al.*, 2019). V večjem številu sta med najdbami od vrst odprtih habitatov prisotni še prepelica (*Coturnix coturnix*) in kavka (*Coloeus monedula*). Zagotovo prisotnost odprtih habitatov v neposredni bližini najdišča potrjujejo najdene nedokončno osificirane kosti juvenilnih osebkov iz rodu *Pyrrhocorax*, kar pomeni, da je šlo za lokalne vrste, ki so na območju gnezdile (pri čemur sta obe vrsti iz tega rodu prilagojeni na gnezdenje v odprtih habitatih) (Rolando *et al.*, 2023).

Delež najdb fosilnih ostankov gozdnih vrst ptic je nizek - le 13%, kar kaže na drugačno vrstno sestavo avifavne kot jo poznamo danes, ko na območju Slovenije prevladujejo gozdne vrste. Med fosilnimi najdbami je tudi fragment karpometakarpusa pripisan rodu *Lagopus*, katerega oba predstavnika, torej barjanskega jereba (*Lagopus lagopus*) in belko (*Lagopus muta*), lahko označimo kot tundrski vrsti. Medtem ko barjanski jereb (*Lagopus lagopus*) na območju Slovenije ni več prisoten in je izključno vrsta tundrskega in borealnega pasu, je belka (*Lagopus muta*) v Sloveniji kot glacialni relik prisotna le v visokogorju nad 1800 metri nadmorske višine (Mihelič *et al.*, 2019).

Najdba pripisana rodu *Lagopus* potrjuje hladnejše razmere na območju, kot jih poznamo danes, vendar pa dejstvo, da je bila temu rodu pripisana le ena najdba, medtem ko so na bližnjih najdiščih, datiranih na višek zadnje poledenitve (npr. Šandalja I in II), najdbe iz rodu *Lagopus* med najpogostejšimi (Tyrberg, 1998), nakazuje na to, da je črnokalsko najdišče 1/II najverjetneje še iz časa pred največjo ohladitvijo, kar je v skladu z radiokarbonskim datiranjem Pavlovca in Poharjeve (1997).

Ker med najdbami izrazito prevladujejo vrste odprtih habitatov (Tab. 3), je mogoče glede na ekološko interpretacijo najdišče umestiti v obdobje glaciala (poledenitve), saj so za interglacialna obdobja v večji meri značilne gozdne vrste (Mourer-Chauvire, 1993; Cimerman, 2024). Na območju Črnega Kala je v tem času glede na vrstno sestavo med najdbami zagotovo prevladovala odprta krajina, ki pa so jo najverjetneje prekinjale tudi posamezne gozdne površine, predvsem v interstadialnih obdobjih. Na takšno mozaično krajino nakazujejo najdbe nekaterih vrst gozdov in gozdnih robov, kot so gozdni jereb (*Tetrastes bonasia*), krekovt (*Nucifraga caryocatactes*), carar (*Turdus viscivorus*), kos (*Turdus merula*) in ščinkavec (*Fringilla coelebs*).

Na podlagi predstavljenih rezultatov je najdišče 1/II nemogoče povsem točno časovno umestiti, sklepamo pa lahko, da gre za eno izmed glacialnih obdobij srednjega pleistocena ali pa za začetek poznega pleistocena. S tem se ujemajo tudi datacije najdišča navedene v drugih objavah (Aguilar *et al.*, 1998; Mihevc, 2001; Jamnik *et al.*, 2013). To bi torej pomenilo, da gre za eno najstarejših najdišč z najdbami fosilnih ostankov ptic na območju celotne Slovenije.

Če datiranje najdišča 1/II dopolnimo z najdbami fosilnih ostankov sesalcev, ki so jih na najdišču 1/I popisali Jamnik in sodelavci (2013), lahko na podlagi prisotnosti ostankov nosorogov (*Stephanorhinus* cf. *kirchbergensis* in *Stephanorhinus* cf. *hemitoechus*) prav tako sklepamo na obdobje srednjega pleistocena in začetek poznega pleistocena, medtem ko bi potrditev določitve najdbe meljaka deningerjevega medveda (*Ursus* cf. *deningeri*) pomenila, da gre verjetneje za srednji pleistocen. Pogostost ostankov jelenov (*Cervus* cf. *elephus*) in srn (*Capreolus* sp.) pa, podobno kot prisotnost gozdnih vrst v vrstni sestavi avifavne, nakazuje na takratno vsaj delno poraščenost območja z gozdno vegetacijo.

ZAKLJUČKI

Namen raziskave je bil opredeliti in predstaviti celovit vrstni seznam fosilnih ostankov ptic z najdišča 1/II v kamnolomu Črni Kal. Z 94 ostanki in 21 določenimi vrstami je to trenutno vrstno najbogatejše pleistocensko najdišče ptic v Sloveniji, objava celotnega seznama pa predstavlja pomemben prispevek k poznavanju pleistocenske avifavne na našem območju. Podrobna interpretacija vrstne sestave in rekonstrukcija paleookolja na podlagi najdb ptic dopolnjujeta dosedanje raziskave v kamnolomu, ki so doslej vključevale predvsem velike sesalce. Z nadaljevanjem rednega paleontološkega monitoringa odpiranja novih najdišč v kamnolomu Črni Kal in vključevanjem tudi najdb ptic in malih sesalcev v paleontološke raziskave bomo lahko naše poznavanje pleistocenskega okolja na tem področju še poglobili.

ZAHVALA

Za nastanek tega članka je bila ključna determinacija zbranega fosilnega materiala z najdišča 1/II, ki jo je opravila Vesna Malez z Zavoda za paleontologijo in geologijo kvartarja Hrvaške akademije znanosti in umetnosti, za kar se ji še posebej zahvaljujemo. Zahvaljujemo se Urški Kačar iz Prirodoslovnega muzeja Slovenije, ki nam je prijazno omogočila dostop do njihove osteološke zbirke. Za pomoč pri zbiranju podatkov o najdbah na drugih najdiščih iz kamnoloma Črni Kal pa se zahvaljujemo še Slavku Polaku iz Notranjskega muzeja Postojna in Mihi Kroflu z Biotehniške fakultete Univerze v Ljubljani.

PLEISTOCENE AVIFAUNA FINDS IN THE ČRNI KAL QUARRY (PRIMORSKA REGION, SLOVENIA)

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SUMMARY

*This paper presents, for the first time, comprehensive data on fossil bird remains from the Črni Kal quarry in Slovenian Istria. The material, collected between 1996 and 2002 at locality 1/II, consists of 94 avian bone elements representing 24 taxa, 21 of which were identified to species level. It is currently the taxonomically richest Pleistocene bird locality in Slovenia. The species list is based on the preliminary identifications by Vesna Malez, which were reviewed and supplemented using osteomorphological literature and the avian osteological collection of the Slovenian Museum of Natural History. Passerines (Passeriformes), particularly the red-billed chough (*Pyrrhocorax pyrrhocorax*), predominate among the finds. Species associated with open habitats represent 61% of all identified specimens (NISP), whereas forest species account for only 13%. The species composition suggests that the site formed under cold glacial conditions, within a mosaic landscape dominated by open habitats interspersed with patches of woodland. Based on the palaeoecological interpretation and in relation to previous published findings and radiometric dates from the Črni Kal sites, we infer that locality 1/II dates to the Middle Pleistocene or the beginning of the Late Pleistocene. As such, it represents the oldest well-documented Pleistocene bird locality in Slovenia and an important contribution to understanding past palaeoenvironments.*

Key words: Črni Kal, fossil finds, birds, avifauna, Pleistocene, palaeoenvironment

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KAZALO K SLIKAM NA OVITKU

SLIKA NA NASLOVNICI: Poševnoprogasta ščetinozobka (*Chaetodon fasciatus)*, endemična vrsta v Rdečem morju in Adenskem zalivu, je dnevno aktivna riba, ki naseljuje predvsem plitve koralne grebene do globine 25 metrov. Pred kratkim se ji je uspelo prebiti skozi Sueški prekop, saj so jo prvič zabeležili v sirskih vodah. (Foto: Borut Furlan)

Sl. 1: Med lesepskimi mehkužci v Sredozemskem morju je najbolj razširjen velikoplavuti grebenski ligenj (*Sepioteuthis lessoniana*). Od prvega dokumentiranega pojava pred skoraj dvema desetletjema je vrsta znatno povečala svojo geografsko razširjenost. (Foto: Borut Furlan)

Sl. 2: Srebrnoproga napihovalka (*Lagocephalus sceleratus)* je invazivna lesepska selivka, katere prisotnost ima znatne ekološke in družbeno-ekonomske posledice za Sredozemsko morje. V Jadranskem morju je bila v preteklosti redko oziroma občasno opažena, zadnji podatki pa kažejo, da se je v zadnjem letu pogostost njenega pojavljanja povečala. (Foto: Borut Furlan)

Sl. 3: Med favnističnimi elementi detritnega peščenega dna v Piranskem zalivu prevladujejo kačjerepi (*Ophiothrix fragilis*), pogosti organizmi pa so tudi številne vrste spužev in kozolnjakov (Ascidiacea). (Foto: Borut Mavrič)

Sl. 4: Navadna plamenka (*Pterois miles*) je bila v Jadranskem morju prvič zabeležena leta 2019. Od takrat je vztrajno napredovala proti severu vzdolž vzhodne jadranske obale – kar so potrjevali vse številnejši zapisi o njenem pojavljanju – in pred kratkim je bila prvič zabeležena tudi v severnem Jadranskem morju. (Foto: Petar Kružić)

Sl. 5: Barvita množica pridnenih nevretenčarjev (epifavna) na detritnem peščenem dnu v Piranskem zalivu. (Foto: Borut Mavrič)

Sl. 6: Lužica na vrhu Jadrana spet odstira nova spoznanja. Vse več je namreč argumentov v prid tezi, da bi Tržaški zaliv (in bližnji severni Jadran) lahko služil kot območje za odraščanje sinjih morskih psov (*Prionace glauca*). (Foto: Borut Furlan)

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COVER PAGE: The diagonal-lined butterflyfish (*Chaetodon fasciatus*), a species endemic to the Red Sea and the Gulf of Aden, is a diurnal fish that primarily inhabits shallow coral reefs at depths of up to 25 metres. Recently, it has crossed the Suez Canal and has been recorded for the first time in Syrian waters. (Photo: Borut Furlan)

Fig. 1: Among Lessepsian cephalopods in the Mediterranean Sea, the bigfin reef squid (*Sepioteuthis lessoniana*) exhibits the widest distribution. Since its first documented record nearly two decades ago, the species has substantially expanded its geographical range. (Photo: Borut Furlan)

Fig. 2: The silver-cheeked toadfish (*Lagocephalus sceleratus*) is an invasive Lessepsian migrant with significant ecological and socio-economic impacts in the Mediterranean Sea. While it was once rare and sporadic in the Adriatic Sea, recent data indicate that the number of occurrences of this species has increased over the past year. (Photo: Borut Furlan)

Fig. 3: The predominant faunal elements of the detrital sandy bottom in the Gulf of Piran are brittle stars (*Ophiothrix fragilis*), while various sponges and sea squirts (*Ascidiacea*) are also common. (Photo: Borut Mavrič)

Fig. 4: The common lionfish (*Pterois miles*) was first recorded in the Adriatic Sea in 2019. Since then, its northward progression along the eastern Adriatic coast has been reflected in an increasing number of documented sightings, and it has recently been recorded for the first time in the northern Adriatic Sea as well. (Photo: Petar Kružić)

Fig. 5: A colourful assemblage of benthic invertebrates (epifauna) on the detrital sandy bottom of the Gulf of Piran. (Photo: Borut Mavrič)

Fig. 6: A puddle at the top of the Adriatic is once again revealing new insights. There is increasing evidence suggesting that the Gulf of Trieste (and the adjacent northern Adriatic) could serve as a nursery area for blue sharks (*Prionace glauca*). (Photo: Borut Furlan)

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