# ANNALES

*Anali za istrske in mediteranske študije*
*Annali di Studi istriani e mediterranei*
*Annals for Istrian and Mediterranean Studies*

*Series Historia Naturalis, 35, 2025, 1*

UDK 5 Annales, Ser. hist. nat., 35, 2025, 1, pp. 1-170, Koper 2025 ISSN1408-533X

UDK 5

ISSN 1408-533X
e-ISSN 2591-1783

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KOPER 2025

Anali za istrske in mediteranske študije - Annali di Studi istriani e mediterranei - Annals for Istrian and Mediterranean Studies

ISSN 1408-533X
e-ISSN 2591-1783

UDK 5

Letnik 35, leto 2025 številka 1

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**Tisk/*Stampa/Print:*** Založništvo PADRE d.o.o.

**Izdajatelja/*Editori/Published by:*** Zgodovinsko društvo za južno Primorsko - Koper / *Società storica del Litorale - Capodistria*©
Inštitut IRRIS za raziskave, razvoj in strategije družbe, kulture in okolja / *Institute IRRIS for Research, Development and Strategies of Society, Culture and Environment / Istituto IRRIS di ricerca, sviluppo e strategie della società, cultura e ambiente*©

**Sedež uredništva/*Sede della redazione/ Address of Editorial Board:*** Nacionalni inštitut za biologijo, Morska biološka postaja Piran / *Istituto nazionale di biologia, Stazione di biologia marina di Pirano / National Institute of Biology, Marine Biology Station Piran*
SI-6330 Piran /*Pirano*, Fornače/*Fornace* 41, tel.: +386 5 671 2900, fax +386 5 671 2901;
*e-mail:* annales@mbss.org, *internet:* www.zdjp.si

Redakcija te številke je bila zaključena 20. 06. 2025.

**Sofinancirajo/*Supporto finanziario/ Financially supported by:*** Javna agencija za znanstveno-raziskovalno in inovacijsko dejavnost Republike Slovenije (ARIS)

***Annales - Series Historia Naturalis*** izhaja dvakrat letno.

**Naklada/*Tiratura/Circulation:*** 300 izvodov/copie/copies

Revija Annales, Series Historia Naturalis je vključena v naslednje podatkovne baze / *La rivista Annales, series Historia Naturalis è inserita nei seguenti data base / Articles appearing in this journal are abstracted and indexed in:* BIOSIS-Zoological Record (UK); Aquatic Sciences and Fisheries Abstracts (ASFA); Elsevier B.V.: SCOPUS (NL); Directory of Open Access Journals (DOAJ).

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**ANNALES · Ser. hist. nat. · 35 · 2025 · 1**

Anali za istrske in mediteranske študije - Annali di Studi istriani e mediterranei - Annals for Istrian and Mediterranean Studies

UDK 5 Letnik 35, Koper 2025, številka 1 ISSN 1408-53 3X
e-ISSN 2591-1783

# VSEBINA / *INDICE GENERALE / CONTENTS*

BIOTSKA GLOBALIZACIJA
*GLOBALIZZAZIONE BIOTICA*
*BIOTIC GLOBALIZATION*

**Okan AKYOL, Oğuzhan TAKICAK & Hasan TARUN**
A Fugitive Lessepsian Fish in a Sea-Cage Farm in the Aegean Sea: *Stephanolepis diaspros* (Monacanthidae) ..... 1
*Ubežni lesepski migrant iz ribogojnice v Egejskem morju:* Stephanolepis diaspros *(Monacanthidae)*

**Nicola BETTOSO, Lisa FARESI, Valentina TORBOLI & Jose A. CUESTA**
Additional Record of the Pea Crab *Pinnotheres bicristatus* (Brachyura: Pinnotheridae) in the Adriatic Sea ..... 7
*Dodatni zapis o pojavljanju stražne rakovice vrste* Pinnotheres bicristatus *(Brachyura: Pinnotheridae) v Jadranskem morju*

**Alan DEIDUN, Sarah BAUMANN, Bruno ZAVA & Maria CORSINI-FOKA**
Confirming the Occurrence of the Non-Indigenous *Pteragogus trispilus* (Actinopterygii: Labridae) within Maltese Waters ..... 13
*Potrditev pojavljanja tujerodne ustnače vrste* Pteragogus trispilus *(Actinopterygii: Labridae) znotraj malteških voda*

**Deniz ERGÜDEN, Yusuf Kenan BAYHAN, Sibel ALAGÖZ ERGÜDEN & Deniz AYAS**
A New Ichthyological Record and Distributional Update for *Epigonus denticulatus* Dieuzeide, 1950 in Turkish Mediterranean Waters ..... 21
*Nov ihtiološki zapis in podatki o razširjenosti rjavega veleokca,* Epigonus denticulatus *Dieuzeide, 1950 v turških sredozemskih vodah*

**Sara LADOUL, Farid HEMIDA, Christian REYNAUD & Christian CAPAPÉ**
On the Occurrence of Cornish Blackfish *Schedophilus medusophagus* (Osteichthyes: Centrolophidae) from the Maghreb Shore (Southwestern Mediterranean Sea) ..... 27
*Potrjena prisotnost meduzojeda* Schedophilus medusophagus *(Osteichthyes: Centrolophidae) z magrebske obale (jugozahodno Sredozemsko morje)*

**Christina MICHAIL & Francesco TIRALONGO**
First Occurrence of Ariidae in Cypriot Waters – a Major Contribution to Biodiversity ..... 35
*Prvo pojavljanje predstavnikov iz družine Ariidae v ciprskih vodah – velik prispevek k biodiverziteti*

SREDOZEMSKE HRUSTANČNICE
SQUALI E RAZZE MEDITERRANEE
*MEDITERRANEAN SHARKS AND RAYS*

**Lovrenc LIPEJ, Riccardo BATTISTELLA, Borut MAVRIČ & Danijel IVAJNŠIČ**
An Insight into the Diet of the Bull Ray, *Aetomylaeus bovinus* (Geoffroy Saint-Hilaire, 1817) in the Northern Adriatic Sea ..... 43
*Vpogled v prehranjevalne navade kljunatega morskega goloba,* Aetomylaeus bovinus *(Geoffroy Saint-Hilaire, 1817) v severnem Jadranu*

**Cem ÇEVİK, Deniz ERGÜDEN & Deniz AYAS**
A New Capture Record of *Alopias superciliosus* Lowe, 1841 from the Turkish Coast (Northeastern Mediterranean) ..... 55
*Nov ulov velikooke morske lisice* Alopias superciliosus *Lowe, 1841 iz turške obale (severovzhodno Sredozemlje)*

**Cem DALYAN, N. Bikem KESİCİ, Elif YÜCEDAĞ BAKIR, Yunus GÖNÜL & Hakan KABASAKAL**
No Longer as Common as its Name: a Review of the Occurrence of *Torpedo torpedo* (Linnaeus, 1758) (Chondrichthyes: Elasmobranchii) in Turkish Waters, with Photographic Evidence ..... 65
*Ni več tako pogost kot njegovo ime: pregled pojavljanja okatega električnega skata* Torpedo torpedo *(Linnaeus, 1758) (Chondrichthyes: Elasmobranchii) v turških vodah s fotografskimi dokazi*

**Deniz ERGÜDEN, Cemal TURAN, Servet Ahmet DOĞDU & Deniz AYAS**
Disc Deformity in a Juvenile Female Brown Ray, *Raja miraletus* (Family: Rajidae), from Northeastern Mediterranean (Türkiye) ..... 73
*Deformacija diska pri juvenilni samici modropege raže,* Raja miraletus *(družina: Rajidae), iz severovzhodnega Sredozemskega morja (Turčija)*

**Farid HEMIDA, Christian REYNAUD & Christian CAPAPÉ**
On an Old Record of the Smalltooth Sand Tiger Shark *Odontaspis ferox* (Chondrichthyes: Odontaspididae) from the Algerian Coast (Southwestern Mediterranean Sea) ..... 83
*O starem zapisu o drobnozobem morskem biku* Odontaspis ferox *(Chondrichthyes: Odontaspididae) z alžirske obale (jugozahodno Sredozemsko morje)*

**Hakan KABASAKAL, Uğur UZER & F. Saadet KARAKULAK**
Plastic Debris-Induced Fin Damage in the Smoothhound, *Mustelus mustelus* ..... 91
*Poškodbe plavuti pri navadnem morskem psu,* Mustelus mustelus, *zaradi plastičnih odpadkov*

**Nicolas ZIANI, Florane TONDU, Rémi BRU, Chloé MOSNIER, Sarah FOXONET, Ruben Bao GALLIEN, Mathias POULY, Modan Lou TONIETTO, Lucille VERDON, Eloïse DEYSSON, Alessandro DE MADDALENA & Hakan KABASAKAL**
Bite Marks Observed on a Large Female White Shark *Carcharodon carcharias* Off Camargue, France Provide Potential Insights into the Reproduction of the Mediterranean Population ..... 97
*Sledovi ugrizov na veliki samici belega morskega volka* Carcharodon carcharias *pri Camargu (Francija) kažejo na možno razmnoževanje sredozemske populacije*

MORSKA FAVNA
*FAUNA MARINA*
*MARINE FAUNA*

**Sihem RAFRAFI-NOUIRA, RIMEL BENMESSAOUD, Mourad CHÉRIF, Christian REYNAUD & Christian CAPAPÉ**
Morphological Deformities in a Common Two-Banded Sea Bream, *Diplodus vulgaris* (Osteichthyes: Sparidae), from Northern Tunisian Waters (Central Mediterranean Sea) ..... 109
*Morfološke deformacije pri fratru,* Diplodus vulgaris *(Osteichthyes: Sparidae), iz severnih tunizijskih vod (osrednje Sredozemsko morje)*

**Abdelkarim DERBALI, Aymen HADJ TAIEB & Wassim KAMMOUN**
The Current Status of *Polititapes aureus* (Mollusca: Bivalvia) in the Coastal Zone of Sfax, Tunisia (Central Mediterranean) ..... 117
*Trenutno stanje vrste* Polititapes aureus *(Mollusca: Bivalvia) na obalnem območju Sfaxa v Tuniziji (osrednje Sredozemlje)*

**Neža LEBAN & Valentina PITACCO**
Current Knowledge on the Distribution of the Poorly Known Echiurid Species *Maxmuelleria gigas* (M. Müller, 1852) in the Slovenian Sea ..... 125
*Trenutno poznavanje prostorske razporeditve manj poznane vrste zvezdaša* Maxmuelleria gigas *(M. Müller, 1852) v slovenskem morju*

**Jan MALEJ, Tjaša KOGOVŠEK, Martin VODOPIVEC, Janja FRANCÉ, Patricija MOZETIČ, Matevž MALEJ & Alenka MALEJ**
Long-Term Study of Zooplankton Biomass in the Gulf of Trieste (Adriatic Sea) ..... 133
*Dolgoročna študija zooplanktonske biomase v Tržaškem zalivu (Jadransko morje)*

**Sihem RAFRAFI-NOUIRA, Rimel BENMESSAOUD, Mourad CHÉRIF, Christian REYNAUD & Christian CAPAPÉ**
Occurrence of the Longjaw Snake Eel, *Ophisurus serpens* (Ophichthidae), in Tunisian Waters (Central Mediterranean Sea) ..... 145
*Pojavljanje zobate jegulje,* Ophisurus serpens *(Ophichthidae), iz tunizijskih voda (osrednje Sredozemsko morje)*

FLORA
*FLORA*
*FLORA*

**Martina ORLANDO-BONACA, Artur BONACA, Diego BONACA & Ana ROTTER**
Seagrasses: a Promising Source of Bioactive Compounds for Human Health Applications ..... 153
*Morske cvetnice: obetaven vir bioaktivnih spojin za uporabo v zdravstvu*

OCENE IN POROČILA
*RECENSIONI E RELAZIONI*
*REVIEWS AND REPORTS*

**Shin-ichi Uye**
Book review: Mirrors of the Sea: When Science and Art Meet. 30 Years of the Unesco Intergovernmental Oceanographic Commission in Slovenia ..... 167

Kazalo k slikam na ovitku ..... 169
***Index to images on the cover*** ..... 169

received: 2025-04-14 DOI 10.19233/ASHN.2025.16

# CURRENT KNOWLEDGE ON THE DISTRIBUTION OF THE POORLY KNOWN ECHIURID SPECIES *MAXMUELLERIA GIGAS* (M. MÜLLER, 1852) IN THE SLOVENIAN SEA

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## *ABSTRACT*

*In September 2024, a specimen of* Maxmuelleria gigas *(*M. Müller, 1852*) was found during a monitoring campaign in the Bay of Koper. This record is the second one of this less known macrobenthic species in the Slovenian Sea and one among few up to date reported in the Adriatic Sea, as well. Sediment mounds observed with an underwater video sledge on muddy bottom in the southern part of the Gulf of Trieste have been related to this species. The species distribution and density (47 per 100 m$^2$) were estimated based on the quantification of the observed sediment mounds. The potential underestimation of the density and distribution of this species in the Gulf of Trieste in the past studies is discussed in relation to sampling method.*

**Key words:** Echiura, sediment mounds, videotransects, Northern Adriatic

# CONOSCENZA ATTUALE DELLA DISTRIBUZIONE DI *MAXMUELLERIA GIGAS* (M. MÜLLER, 1852), SPECIE DI ECHIURIDE POCO CONOSCIUTA, NEL MARE SLOVENO

## *SINTESI*

*La prima segnalazione di* Maxmuelleria gigas *(*M. Müller, 1852*) nelle acque slovene risale al 2020. In settembre 2024, è stato rinvenuto un secondo esemplare di questa specie durante una campagna di monitoraggio nella Baia di Capodistria. Durante alcuni campionamenti con l'uso di una videocamera subacquea sui fondali fangosi nella parte meridionale del golfo di Trieste, sono stati rilevati dei coni di sedimento che vengono attribuiti a questa specie. La distribuzione e la densità della specie (47 per 100m$^2$) è stata stimata sulla base del conteggio dei cumuli di sedimento osservati. Viene discussa la potenziale sottostima della densità e della distribuzione di questa specie nel Golfo di Trieste nei lavori precedenti, in relazione al metodo di campionamento.*

**Parole chiave:** Echiura, cumuli di sedimento, videotransetti, Nord Adriatico

## INTRODUCTION

Named for their spoon-like proboscis, the Echiura or spoon worms, are present in soft-bottom marine environments from the intertidal to the deep sea (Biseswar, 2009; Hughes *et al.*, 1996a). The pelagic stage in their larval development, as well as their ability to withstand wide range of temperature and salinity, enables them to colonize vast areas from the Atlantic to the Indo-West Pacific ocean (Biseswar, 2009, 2012). Out of the six species known in the Mediterranean (Murina, 1984) only two have been recorded in the Adriatic Sea: *Bonellia viridis* (Zavodnik, 2016) and *Maxmuelleria gigas* (Atkinson *et al.*, 1998; Minelli *et al.*, 2003; Simonini *et al.*, 2007). While the first has been observed in the past (Lipej & Vrišer, 1999; Sket, 2003), the latter was only recently recorded for the first time in the Slovenian Sea (Pitacco, 2020).

The species of the genus *Maxmuelleria* inhabiting soft sediments build U-shaped burrows, 42 cm deep (Nickell *et al.*, 1995), with two openings on the surface that can be up to 100 cm apart (Hughes *et al.*, 1996b). One of the openings is used primarily for feeding while the other serves as an excretory vent for the sediment discharge. Animals were observed to be located towards one side of the burrow, from where they extend their spoon-like proboscis to collect the surface sediments (Hughes *et al.*, 1996a), carrying it towards the funnel-shaped opening, measuring 4 cm in diameter (Nickell *et al.*, 1995). The expulsion of sediment in the form of a blow or fluidized slurry on the other side of the tunnel can result in a formation of a sediment mound around the opening, which can grow up to 60 cm wide and 30 cm high (Moore *et al.*, 2013) in the shape of a dome or a sharp cone. While the active ejection of sediment can be observed throughout the day, the appearance of proboscis, retracting suddenly when shined on by a light, could only be recorded by night with an infrared-sensitive camera (Hughes *et al.*, 1996a). All information on the burrow structure and feeding activity was derived from the observation of *Maxmuelleria lankesteri* (Herdman, 1897) in the Northern Atlantic. However, besides some differences in the distribution of papillae on proboscis, *M. lankesteri* and *M. gigas* are believed to be closely related species, which some authors consider the same (Stephen & Edmonds, 1972).

Active specimens of *Maxmuelleria lankesteri* were usually observed with an underwater television camera (Hughes *et al.*, 1996a) or while SCUBA diving (Nickell *et al.*, 1995). The shape of their burrows was described based on the shape of resin casts, where polyester or epoxy material was poured into the burrow to obtain its shape when hardened (Seike *et al.*, 2012). The few records reporting the species *M. gigas* in the Adriatic mostly rely on the observation of active proboscis (Atkinson *et al.*, 1998) and the presence of sediment mounds (Zavodnik, 2016) for species identification. Recently, a live specimen was caught off Koper, Slovenia, which confirmed the presence of *M. gigas* in Slovenian waters (Pitacco, 2020). The present study introduces the second record of *M. gigas* in the Slovenian Sea, as well as the estimated distribution of the species, which was derived from integrated point sampling data obtained with Van Veen grab and visual data obtained with underwater video transects.

## MATERIAL AND METHODS

A specimen of *M. gigas* was captured on September 23rd, 2024, during a monitoring project of soft-bottom macrofauna in the waters of Slovenia, North Adriatic (Fig. 1). Sediment samples were taken with the Van Veen grab (0.1 $m^2$) at a depth of 22.3 m at the sampling location (45.591667°N, 13.666667°E), 2.8 km west of the Punta Grossa, on a soft-bottom sediment floor; 53% silt, 27% clay and 20% sand with 40-50% carbonate content (Ogorelec *et al.*, 1991). The specimen was pinched with the grab scoop, which caused damage to the body wall and evisceration. The animal was released after being photographed. Van Veen grab is used for sampling of infaunal species, present in the upper layers of the sediment (Mackie *et al.*, 2007).

Linear video transects of the soft bottom were recorded by a video sledge (SKIKAM) during an observation of circalittoral benthic habitats in the Slovenian Sea. The study was carried out by the Marine Biology Station, Piran (National Institute of Biology, Slovenia) from 2021 to 2023 under the project "An upgrade on knowledge of biotic and abiotic characteristics and extent of benthic habitat types of circalittoral coarse sediments (MC3), circalittoral mixed sediments (MC4) and circalittoral sands (MC5)" (Mavrič *et al.*, 2023). The transects covered an area of 13046 $m^2$, with a mean depth of 22.4 m and pelite content ranging from 20% to 60%. In this study, cone-shaped structures associated with *Maxmuelleria* burrows were observed and counted. The sediment mounds surrounding a burrow opening were mostly observed individually; occasionally, two to three mounds were merged with the respective number of openings observed on top. The counting criteria included the presence of an open burrow opening (not closed with sediment) surrounded by a sediment mound; in the case of merged mounds, one opening was counted as one mound. The sign of activity was marked in case of a light colored sediment (fluidized slurry) present on top of a mound around the opening as described by Hughes *et al.* (1996a) and Atkinson *et al.*(1998). Occasionally, blows of sediment were observed coming from the top of the mound. The mound density was calculated in relation to the surface area covered by the video transects, analyzed for this study (5166.6 $m^2$).

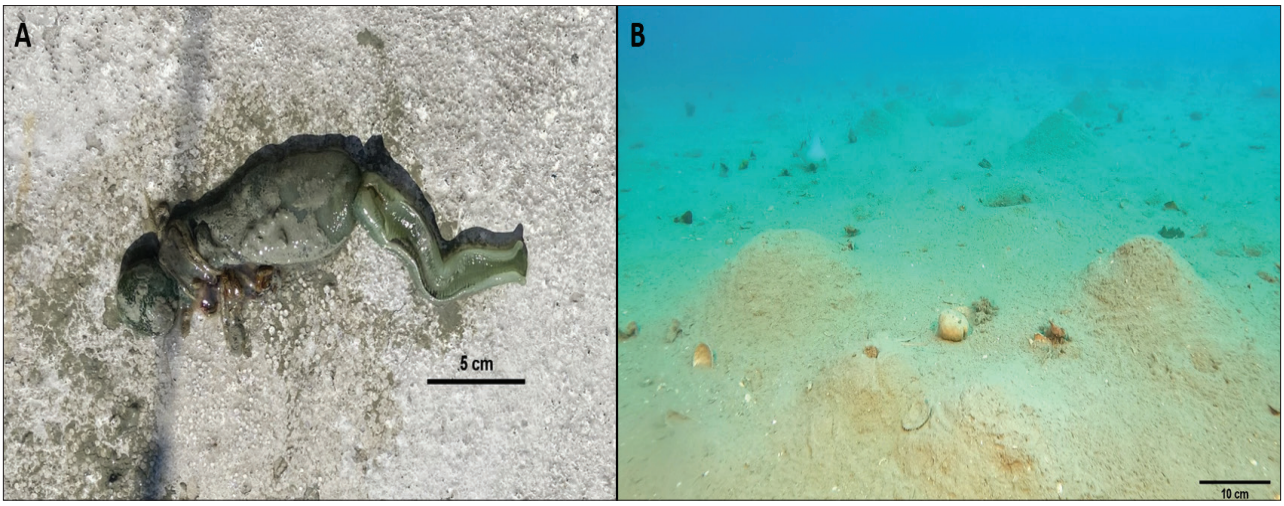


***Fig. 1:*** *Maxmuelleria gigas*. ***A) Whole specimen, ventral view, B) sediment mounds, associated with*** *M. gigas*, ***found on the soft bottom in the Gulf of Trieste.***
***Sl. 1:*** *Maxmuelleria gigas*. ***A) Primerek s trebušne strani, B) sedimentni hribčki povezani z*** *M. gigas*, ***najdeni na sedimentnem dnu v Tržaškem zalivu.***

## RESULTS AND DISCUSSION

The specimen collected in 2024 represents the second record of *Maxmuelleria gigas* in the Slovenian Sea. It measured 11 cm in total length and was identified as *M. gigas* (M. Müller, 1852) based on a non-bifid proboscis and a green colored sausage-like body (Fig. 1A). Green coloration of the echiurid is not related to chlorophyll, but instead comes from a chlorin pigment bonellin, which has proven to cause cytolysis and toxic effects on spermatozoa and echinoid egg development (Agius *et al.*, 1979). The cytolysis and other effects turned out to be accelerated by light (photodynamic action), which could serve as a defense mechanism if released in the environment in the presence of predators (Agius *et al.*, 1979).

Sediment mounds (Fig. 1B), have been observed in high quantities (47 per 100 m$^2$; overall surface area 5166 m$^2$) during the sampling of the seafloor by a video-sledge (SKIKAM) in the northeastern part of the Gulf of Trieste (Fig. 2). They were similar to those associated with *Maxmuelleria lankesteri* in Scotland (Hughes *et al.*, 1996b). The mounds were mostly observed individually (75%) and with clear openings (99.6%), where signs of activity were scarcely present (3%), mostly in the form of fluidized slurry around the opening. Most of the time, these mounds had other openings on the sides or in their vicinity, probably made by other burrowing species of crustaceans (e.g. *Squilla mantis, Nephrops norvegicus*) and fish. The black goby (*Gobius niger*) was observed dwelling near the burrow openings (0.9 per 100 m$^2$), where it fled once the video-sledge approached; the brown comber (*Serranus hepatus*) was observed hiding behind the mounds (2 per 100 m$^2$), carefully observing the approaching sledge before fleeing the field of view; one sighting of a fleeing shrimp included a tail disappearing into one of the holes on the side of a sediment mound.

The mounds were observed in higher density (81 per 100 m$^2$; surface area 2243.2 m$^2$) on predominantly muddy seafloor with high proportions of silt (50–60%) in the inner parts of the Gulf of Trieste, on the southern opening of the Bay of Koper (Fig. 2, green). The density of mounds decreased (17 per 100 m$^2$; surface area 3297 m$^2$) moving off-shore, where silt content in bottom sediments is lower (40–50%) (Fig. 2, blue). Silt content in sediments is known as a key factor influencing benthic communities in the studied area (Pitacco *et al.*, 2023). Higher density of mounds in the areas with larger proportion of silt can be related to the high detritus quantity in the surface sediment layers favoring the establishment of detritus-feeding macrobenthic communities (Rosenberg, 1995; Pan & Pratolongo, 2021).

Similar structures to sediment mounds were described in the area offshore Ancona, Italy (Atkinson *et al.*, 1998) and related to *M. gigas* as the only sediment-burrowing species of echiurids recorded in the Adriatic Sea (Zavodnik, 2016). These structures have been related to *M. gigas* due to the emergence of the proboscis, observed by underwater television recordings first by Atkinson *et al.* (1998) in Ancona and later recorded by divers in the area of Fiesa, Slovenia, in March 2023 (C. Mlinar Cic & B. Mavrič, *personal communication*). In the latter, the proboscis was observed retracting into the inhalant burrow, carrying a load of sediment into the opening in an action resembling a conveyor belt.

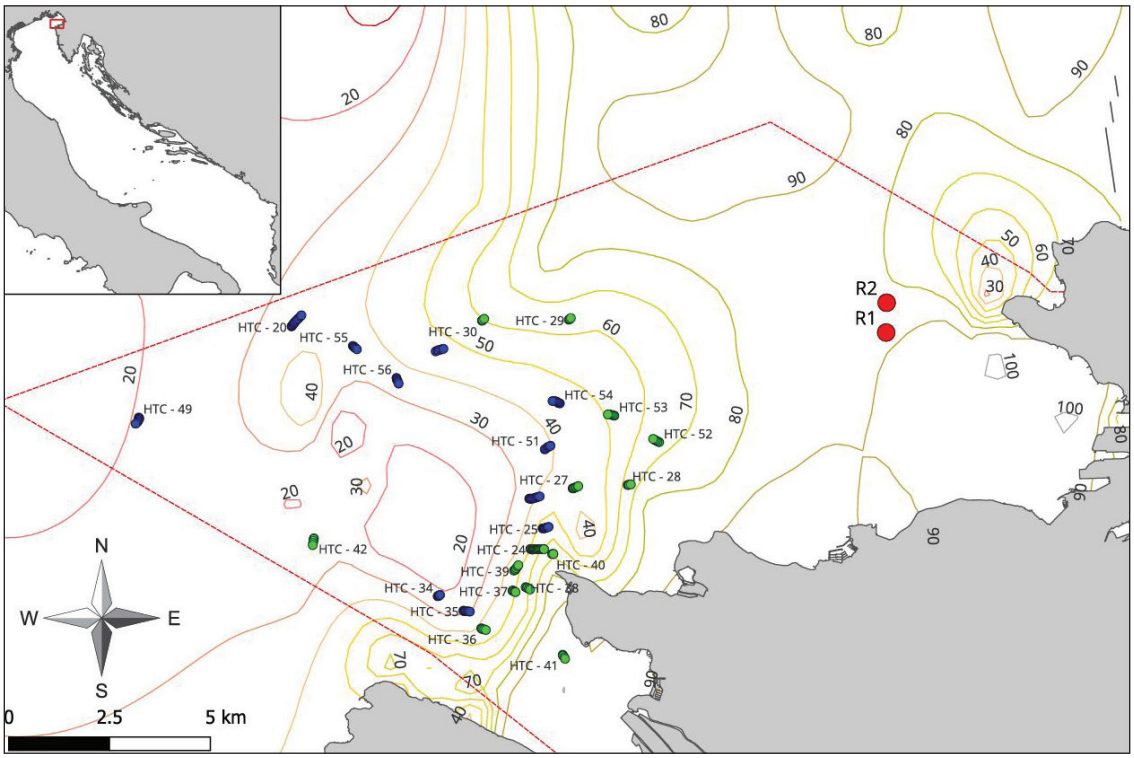


***Fig. 2: A map of the study area in the Slovenian Sea. GPS positions of the video transects are marked in blue and green. The silt content in sediment (%) is marked by isoclines. The points in red present the GPS positions of the first (Pitacco, 2020; R1) and second record of this species (present work; R2).***
***Sl. 2: Zemljevid obravnavanega območja slovenskega morja. Z zeleno in modro barvo so označene GPS lokacije video transektov. Vsebnost pelita v sedimentu (%) je označena z izoklinami. Z rdečo sta označeni GPS lokaciji prvega (Pitacco, 2020; R1) in drugega zapisa o pojavljanju vrste (to delo; R2).***

However, no systematic sampling of these organisms has been done in the Northern Adriatic, which would provide direct association of each burrow and sediment mound to the presence of this species; therefore, we cannot assume the exclusivity of other burrowing fauna creating or inhabiting these kinds of sediment mounds. While the activity of the proboscis leaves little doubt in the identification, the mound structures of *M. gigas* can otherwise be recognized by a layer of ejected sediment of different color around the opening, with occasionally present faecal pellets 2-4 mm long and 0.7-1 mm wide (Hughes *et al.*, 1996a).

Some species of burrowing shrimp (*Necallianassa truncata, Gliyossius tyrrhenea, Jaxaea nocturna*) create similar sediment mounds around one of the burrow openings, however, the size of the mound is usually smaller than the one of *M. gigas* (Pervesler & Dworschak, 1985; Moore *et al.*, 2013), while the other opening is usually in the shape of a funnel (Ziebis *et al.*, 1996; Dworschak, 2001). Other species of sediment-dwelling shrimp usually build burrows with more than two openings (*Upogebia pusilla, U. tipica, Squilla mantis, Nephrops norvegicus*), which have a sediment excrete present around the opening, but never in the shape of a discrete mound (Rice & Chapman, 1971; Atkinson *et al.*, 1997, 1998; Dworschak, 2004). Other burrowing species present on the soft muds of the Northern Adriatic (*Solecurtus strigilatus, Brachynotus gemmellari, Gobius niger*) were also observed on the same grounds as the mounds of *M. gigas* (Nickell *et al.*, 1995; Moore *et al.*, 2013), however, their burrow structures do not resemble the ones associated with the echiurid; *S. strigilatus* builds burrows swith openings flush with the surface, 3 – 6 cm apart (Dworschak, 1987); the burrows of *B. gemmellari* are a shallow excavation, with only one opening (Atkinson *et al.*, 1998); *G. niger* usually settles in abandoned shrimp burrows, where it modifies one of the openings to create a chamber close to the surface (Atkinson *et al.*, 1998).

Despite biannual samplings of sediment grabs along the Slovenian coast from 2007 onward (http://www.arso.gov.si/vode/podatki/), this species was considered rare in the Northern Adriatic (Pitacco, 2020). Although grab sampling is used for collecting soft-bottom burrowing fauna in the Northern Adriatic (Pitacco *et al.*, 2023), grabs and corers are not suitable for deep-burrowing

organisms, which live below the penetration of most samplers with the average sediment penetration depth 20 cm, the deepest 45 cm (Mackie *et al.*, 2007); while a relative species *Maxmuelleria lankesteri* burrow can reach up to 80 cm deep (Hughes *et al.*, 1996b). The previous lack of records in the Northern Adriatic may be due to the limitation of this point-sampling method. The method of resin casts made from the hardened material in the shape of the mold is widely used for describing the morphology of burrows, mostly made by burrowing crustaceans (Pervesler & Dworschak, 1985; Atkinson *et al.*, 1997; Dworschak, 2001) and gobies (Rice & Johnstone, 1972; Atkinson *et al.*, 1998). However, it is not optimal for discovering the true occupancy of the burrow, especially for the echiuran species, where only the slight green coloration of the resin cast can hint at the presence of the animal (Hughes *et al.*, 1996b). Sampling with ship-borne equipment and in situ with SCUBA are also limited by the surface of the area studied, while underwater television is more suitable to cover large areas of soft-sediment floor.

The underwater television observation technique has proven efficient in the stock assessment of the Norwegian shrimp (*N. norvegicus*) (Naseer *et al.*, 2022), however, there is still too little information of the burrowing structure of *M. gigas* to completely exclude the doubts surrounding burrow identification, burrow detection, counting strategies and most importantly occupancy assessment (Marrs *et al.*, 1996). While the strategy of "one burrow, one animal" has been adjusted for the Norwegian shrimp, further studies on the echiuran abundance in the Northern Adriatic are needed, before implementing similar density estimation strategies.

Although the ecology of the genus *Maxmuelleria* is poorly known, studies from the Irish Sea suggest their great importance in the role of bioturbation of soft sediments, overturning 13 g of dry sediment a day (Hughes *et al.*, 1996b). The sediment mounds on the seafloor also increase the surface area, consequently enhancing the benthic flux (King, 2011). The density of 120 sediment mounds per $m^2$ created by a burrowing shrimp *Necallianassa truncata* increased the surface of the sediment-water interface by 400% (Ziebis *et al.*, 1996). Furthermore, oxygenation of upper sediment layers was increased by a factor of 1.5 on the seafloor with a high density of sediment mounds (22 mounds per $m^2$), where oxygen penetrated deeper (40 mm) around a mound than on a smooth surface (4 mm) (Ziebis *et al.*, 1996). Besides increasing the surface-water interface area, the mounds create a more structured seafloor providing habitat also for bottom dwelling fish such as the black goby, which is known for its opportunistic use of burrows, mostly reworking the upper parts of the burrows of Maxmuelleria and infaunal shrimps (*Squilla mantis, Callianassa subterranea*) (Atkinson *et al.*, 1998).

The high number of sediment structures observed in the present work on video-recordings indicated that the true density and distribution of *M. gigas*, together with its ecological role, have been underestimated so far.

## ACKNOWLEDGEMENTS

This work was possible thanks to the financial support of the Agency for Environment within national monitoring of the Ecological status of coastal waters within the Republic of Slovenia, and of the Slovenian Research Agency (research core funding No. P1-0237).

The authors thank Tihomir Makovec, Tristan Bartole, Simone Spinelli and Moira Buršić for their help during sampling and Milijan Šiško for the help with graphic material. Thanks also to dr. Borut Mavrič and Ciril Mlinar Cic for their input. Special thanks to Prof. dr. Lovrenc Lipej for his advice and encouragement.

# TRENUTNO POZNAVANJE PROSTORSKE RAZPOREDITVE MANJ POZNANE VRSTE ZVEZDAŠA *MAXMUELLERIA GIGAS* (M. MÜLLER, 1852) V SLOVENSKEM MORJU

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*POVZETEK*

*Septembra 2024 je bil najden osebek vrste* Maxmuelleria gigas *(*M. Müller, 1852*) med vzorčenjem v Koprskem zalivu. Poleg redkih opažanj te vrste v Jadranskem morju, ta najdba predstavlja drugega in enega od novejših zapisov pojavljanja te vrste v slovenskem morju. Sedimentni hribčki, opaženi z video sanmi na muljastem sedimentnem dnu v Tržaškem zalivu, so bili povezani z dejavnostjo te vrste. Razporeditev in gostota osebkov (47 na 100 m$^2$) sta bili ocenjeni na podlagi pojavljanja sedimentnih hribčkov. Avtorici obravnavata morebitno podcenjenost gostote pojavljanja te vrste v Tržaškem zalivu, v povezavi z vzorčevalno metodo.*

**Ključne besede:** Echiura, sedimentni hribčki, podvodni videozapisi, severni Jadran

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