

SHORT COMMUNICATION

Crossing frontiers *Tubulophilinopsis lineolata* reaches the Mediterranean: A new record from the Libyan Coast

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Abstract: The Mediterranean Sea is significantly impacted by non-indigenous species (NIS) that have arrived through various routes, most notably shipping traffic. As a result, commercial harbours have become critical hotspots for these introductions. The Libyan coastline, particularly in the vicinity of major ports, is highly vulnerable to the arrival of NIS. During a targeted assessment of heterobranch biodiversity conducted from 2023 to 2025, the cephalaspidean *Tubulophilinopsis lineolata* was documented for the first time in both Libya and the Mediterranean Sea. This discovery highlights the urgent need for increased monitoring and for the creation of systematic biodiversity inventories covering Libya's understudied coastal regions.

Keywords: alien species; North Africa; non-indigenous species; sea slug; Australia; Surman; Indo-Pacific; ballast water

Sažetak: PRELAZEĆI GRANICE *TUBULOPHILINOPSIS LINEOLATA* STIŽE U SREDOZEMLJE: NOVI NALAZ S LIBIJSKE OBALE. Sredozemno more nalazi se pod značajnim utjecajem alohtonih vrsta koje su pristigle na različite načine, ponajprije pomorskim prometom. Zbog toga su trgovačke luke postale ključne točke njihovog unosa. Libijska obala, osobito područja u blizini velikih luka, vrlo je podložna dolasku stranih vrsta. Tijekom ciljane procjene bioraznolikosti morskih puževa iz podrazreda Heterobranchia provedene od 2023. do 2025. godine, vrsta *Tubulophilinopsis lineolata* iz reda Cephalaspidea prvi je put zabilježena u Libiji i u Sredozemnom moru. Ovo otkriće naglašava žurnu potrebu za intenzivnijim praćenjem te uspostavom sustavnih popisa bioraznolikosti koji bi obuhvatili nedovoljno istražena obalna područja Libije.

Ključne riječi: strane vrste; Sjeverna Afrika; alohtone vrste; morski puž golač; Australija; Surman; Indo-Pacifik; balastne vode

INTRODUCTION

The Mediterranean Sea is increasingly impacted by non-indigenous species (NIS) that have arrived through various routes and vectors, including the Suez Canal and shipping traffic (Zenetos *et al.*, 2010, 2025). Furthermore, the settlement of NIS is believed to be facilitated by global climate change, which has a significant impact on the Mediterranean region (Albano *et al.*, 2021). Among the NIS recorded in the basin, the molluscan taxon, comprising over 222 species, is one of the most well documented (Galanidi *et al.*, 2023). Among them, some heterobranch sea slugs are rarely recorded, while others form localized (Rizgalla, 2025a) or stable populations (Rizgalla *et al.*, 2019; Zenetos *et al.*, 2022; Castriota *et al.*, 2025).

Until recently, the genus *Tubulophilinopsis* (formerly *Philinopsis*; see Zamora-Silva and Malaquias, 2017) was represented in the Mediterranean only by a single record. Galinou-Mitsoudi *et al.* (2023) first identified the genus based on a shell recovered from depths of 40–100 m. This was followed by Christidis *et al.* (2024), who confirmed the presence of *Tubulophilinopsis reticulata* (Eliot, 1903) in shallow waters (30 cm) of Tunisia's El Biban lagoon.

In contrast, the cephalaspidean sea slug *Tubulophilinopsis lineolata* (H. Adams & A. Adams, 1854) (Cephalaspidea, Aglajidae) is typically found in the Indo-West Pacific region (Rudman, 1998; Zamora-Silva and Malaquias, 2017). This species typically inhabits intertidal zones and soft sediments such as sandy mud at depths reaching 18 m (Rudman, 1998; Mehrotra *et al.*, 2021).

Its colouration is primarily creamy white with narrow, dark brown transverse bands that may merge (Zamora-Silva and Malaquias, 2017); variations ranging from very dark to lighter shades have also been documented (Rudman, 1972, 1998; Burn, 1978). The body is elongated and typically cylindrical, featuring small parapodia and a blunt posterior edge on the headshield. The anterior edge of the cephalic shield is bilobed with blue margins. A distinguishing characteristic is the rounded central crest on the head, known as a cephalic hump (Zamora-Silva and Malaquias, 2017). This feature is created by the long, muscular pharynx (buccal bulb), a specialized, tube-like proboscis which forms the bump when retracted (Rudman, 1998). Like other members of Aglajidae, *T. lineolata* is a predator that is typically active at night, though the exact function of its tube-like pharynx remains uncertain (Rudman, 1998).

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Within the context of assessing heterobranch sea slug biodiversity in Libyan waters, seven NIS have been documented to date (e.g., Bek-Benghazi *et al.*, 2020; Rizgalla *et al.*, 2025; Rizgalla, 2025a). Among these, only two species belonging to the Aglajidae family have been identified: the native *Camachoaglaja africana* (Pruvot-Fol, 1953) (Rizgalla, 2025b) and the NIS *Biuve fulvipunctata* (Baba, 1938) (Rizgalla and Christa, 2025). Both were recorded in the western region at sites separated by more than 60 km, with evidence suggesting the presence of established populations of *B. fulvipunctata* at both locations (Rizgalla and Christa, 2025). The objective of the present study is to provide the first record of the NIS *T. lineolata* from the western coast of Libya and the Mediterranean Sea.

MATERIAL AND METHODS

Study area

The study was conducted at Surman Family Beach, a natural bay located approximately 60 km west of Tripoli (32°47'49.6" N, 12°33'51.3" E; Fig. 1A). The bay is characterized by sandy and rocky substrates with a maximum depth of 2–3 m. The site is in close proximity to the Zawia oil refinery, which is situated approximately 11 km to the east (32°47'37.3" N, 12°40'40.6" E; Fig. 1).

The bay was surveyed *via* snorkelling during three periods: September–October 2023, March–August 2024, and January, March, and July–September 2025. Mixed algal substrates were collected from the low-tide area down to a depth of 1.5 m. Samples were main-

tained in non-aerated plastic containers and periodically screened for specimens.

Live specimens were observed using both dissecting and compound microscopes, and photographed with an Olympus Tough TG-7 underwater camera. Finally, specimens were fixed in 10% neutral buffered formalin and 96% ethanol for long-term preservation.

Species morphological identification

The specimens were morphologically identified to the species level through the examination of external features and comparison with existing literature (e.g., Rudman, 1998; Zamora-Silva and Malaquias, 2017) and online databases, including the Sea Slug Forum and iNaturalist. Taxonomic assignments followed the World Register of Marine Species (WoRMS). The total length of live specimens was measured to the nearest 1 mm using a tape measure.

RESULTS AND DISCUSSION

Seven specimens of *Tubulophilinopsis lineolata* were identified within a mixed algal substrate at depths ranging from 40 to 50 cm (Table 1). Diagnostic features included a cream-to-white body with narrow, dark

Table 1. Seven *Tubulophilinopsis lineolata* specimen found at the natural bay of Surman.

Date	Size (mm)	Figure
21 Aug 2025	4	2A
22 Aug 2025	5.5	2B
30 Aug 2025	3	2C
2 Sept 2025	3	
5 Sept 2025	7	2D
6 Sept 2025	6	2E
8 Sept 2025	6	2F

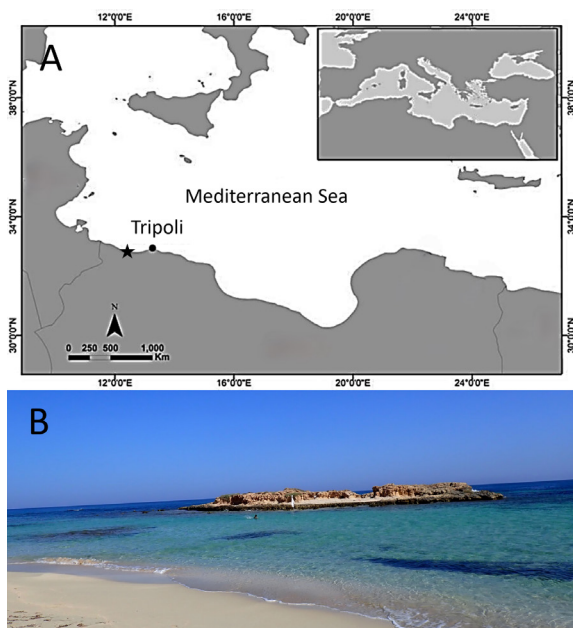


Fig. 1. Map of the study area, with the sampling site at Surman indicated by a star, located 60 km west of Tripoli (A); the mixed sandy and rocky substrate of the natural bay at Surman (B).

brown longitudinal lines that occasionally merge. The body is elongated and cylindrical, featuring a prominent central crest (hump) on the head, two posterior “tails” (one longer than the other), and bright blue or white margins on the parapodial flaps. The dorsal eyes were positioned anteriorly on the cephalic shield within unpigmented patches (Fig. 2). Although the characteristic cephalic bulb was present, it was less developed than in the larger specimens described by Rudman (1998), suggesting these individuals may be immature. Notably, one specimen exhibited a bulging right eye, a morphological anomaly previously documented in malacological studies (Rudman, 2000; Rizgalla *et al.*, 2025).

Tubulophilinopsis lineolata is the second Indo-Pacific member of the Aglajidae family recorded in the



Fig. 2. *Tubulophilinopsis lineolata* (H. Adams & A. Adams, 1854) - lateral view of *T. lineolata*; the white arrow indicates the characteristic bump on the cephalic shield (**A**, **B**); a specimen exhibiting darker colouration (**B**); *Tubulophilinopsis lineolata* in situ (**C**); dorsal view of a 7 mm long specimen (**D**); a 6 mm specimen showing a morphological anomaly of the right eye (white arrow), possibly due to malformation or injury; the inset shows the normal positioning of eyes within unpigmented periorcular areas (**E**); a darker specimen measuring 6 mm (**F**).

study area. While *B. fulvipunctata* has been recorded in Libya from Surman and Tripoli, it is a species already documented within the Mediterranean basin (Rizgalla and Christa, 2025). In contrast, *T. lineolata* was only recorded now from Surman and is currently unknown in the rest of the basin.

The proximity of Surman to the oil hub of Zawia strongly supports a ship-mediated arrival. This is a pathway often considered one of the primary vectors for NIS introduction to the Mediterranean Sea (Molnar *et al.*, 2008; Costello *et al.*, 2022). Furthermore, the protected environment of Surman offers ideal conditions for

the settlement of non-indigenous species (Rizgalla and Christa, 2025).

Descriptions of the spawning patterning and egg masses' morphology for *T. lineolata* remain unavailable in the literature, and no egg strings were detected within the substrate. While adults are visually striking, reaching lengths of 20–45 mm (Rudman, 1998; Mehrotra *et al.*, 2021), and frequently documented by citizen scientists (Chow *et al.*, 2022; Taylor, 2024), the specimens in this study measured only 2–7 mm. This size discrepancy suggests the individuals were likely juveniles. Furthermore, their exclusive appearance between August and

September 2025, following absences in previous surveys, may indicate a recent introduction to the area.

However, because no surveys were conducted in February or between November and December, the seasonal record remains incomplete. This temporal data gap prevents a definitive determination of the species' invasive status. Following the framework established by Vanhellemont (2009), the species was classified as a "casual occurrence," pending more comprehensive data.

The present record is the first documentation of *T. lineolata* in both Libya and the Mediterranean Sea. This occurrence could indicate an independent introduction, possibly aided by proximity to the commercial harbour of Zawia. While natural spread from neighbouring, undiscovered populations via prevailing currents remains a possibility (Azzola *et al.*, 2025), anthropogenic transport is a more likely explanation at this time.

This discovery emphasises the importance of biodiversity assessments along the Libyan coastline, where many species likely remain undetected. While sea slug research in Libyan waters has increased in recent years, primarily in the western region (e.g., Rizgalla *et al.*, 2025), there is significant need to expand these studies to other locations along the coast.

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