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BILEL BENSARI, LAMIA BAHBAH, ADEL KACIMI, RYM BACHETARZI, NOUR EL ISLAM BACHARI

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Non-indigenous and cryptogenic marine species in the Port of Algiers (Western Mediterranean)

Bilel BENSARI[1], Lamia BAHBAH[1,2], Adel KACIMI[3], Rym BACHETARZI[1], and Nour El Islam BACHARI [1]

[1]Biological Oceanography and Marine Environment Laboratory, Faculty of Biological Science, University of Science and Technology, Houari Boumediene. B.P 32 El Alia 16111 Bab Ezzouar, Algeria
[2]National Higher School of Marine Sciences and Coastal Management, 16320 Algiers, Algeria
[3]Marine and Coastal Ecosystems Laboratory (ECOSYSMarL), Department of Marine and Coastal Environment, National Higher School of Marine Sciences and Coastal Management, 16320 Algiers, Algeria

Corresponding author: Bilel BENSARI; bilel.bensari_fsb@usthb.edu.dz

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Abstract

This study addresses the growing concern of non-indigenous and cryptogenic marine species in the Mediterranean Sea, particularly in high-risk zones such as ports. The Port of Algiers, a significant maritime hub in Algeria, was selected as the study site to document the presence of such species due to its susceptibility to introductions through vessel traffic. Sampling was conducted from 2021 to 2024 across various submerged structures, including mooring buoys and ship fenders. Specimens were collected by scraping surfaces and preserved for identification, which was performed to the lowest taxonomic level possible. The results revealed 18 distinct species, of which 13 were non-indigenous and five cryptogenic. Notably, 11 of these species are recorded for the first time on the Algerian coast. Taxonomically, the species included Ascidiacea (six species), Bryozoa (five species), Crustacea (three species), Polychaeta (three species), and Porifera (one species). This research contributes to the baseline knowledge of non-indigenous and cryptogenic species in Algerian marine environments, providing essential data to support further ecological and biogeographic studies on species introductions in the Mediterranean Sea.

Keywords: Non-indigenous species; Cryptogenic species; Fouling species; Algerian coast; Port.

Introduction

The introduction of non-indigenous marine species (NIS) has become a significant environmental issue worldwide, with profound ecological, economic, and social implications (Ruiz *et al.,* 1997). Non-indigenous species often compete with native species, alter habitats, and disrupt local ecosystems, leading to biodiversity loss and ecosystem imbalances (Katsanevakis *et al*., 2014). In the Mediterranean Sea, one of the world's most invaded regions, the problem is particularly pronounced due to the basin's high volume of maritime traffic, diverse habitats, and connectivity with the Atlantic Ocean and the Red Sea through the Suez Canal (D'Amen & Azzurro, 2020; Katsanevakis *et al.,* 2014; Zenetos *et al.,* 2010). This connectivity facilitates the spread of species from other regions, making the Mediterranean region a hotspot for biological invasions.

Among the primary pathways of NIS introduction, maritime vessels play a crucial role, mainly through ballast water discharge and hull fouling (Bouda *et al*., 2016, 2018; Gollasch, 2002). Ports, as key entry points for shipping, are thus critical zones for NIS risk assessment, as they can serve as initial settlement areas for NIS potentially able to become invasive (Tempesti *et al*., 2020; Ulman *et al*., 2017). Monitoring these high-risk areas is essential for managing and mitigating the arrival and establishment of NIS.

Despite the Mediterranean's status as an invasion-prone sea, the study and monitoring of non-indigenous species in Algeria remain limited (Grimes *et al.*, 2018), particularly in ports. To date, only one study has investigated NIS in Algerian ports, highlighting a gap in consistent monitoring and research on this critical issue (Bensari *et al*., 2020). This lack of comprehensive data presents challenges in developing effective management and conservation strategies to address biological invasions.

The present study aims to fill this knowledge gap by reporting on several NIS observed in the Port of Algiers, contributing valuable data to the limited body of research on this subject. Through this research, we aim to enhance understanding of NIS dynamics in Algerian waters and emphasise the need for regular monitoring to formulate management actions and minimise the impact of future invasions.

Material and Methods

The study was conducted at the Port of Algiers (Fig. 1), one of the oldest ports in Algeria. Various submerged structures, including ropes, ship fender tires, steel dock posts, and the quay surface, were selected as sampling sites. These structures, located at depths not exceeding 2 m, were chosen based on their potential to support a diverse range of marine species. The characteristics of each station, including coordinates, substrate type, and sampling dates, are summarised in Table 1. To optimise species detection, multiple sampling campaigns were conducted. Sampling focused on structures that could be lifted onto the quay, as well as the upper part of the quay. Additionally, an underwater camera was submerged a few centimeters to capture images of species adhering to the quay surface.

Specimens were collected by scraping them off submerged surfaces by using a putty knife, a method that facilitated retrieval while minimizing damage. The sampled organisms were immediately preserved in a 5% formalin solution to maintain their integrity. Although the precise sampling area was not measured, species abundance was estimated qualitatively as low, medium, or high.

Some specimens were identified on-site, which were recognised based on clearly visible morphology. Other specimens were identified using a stereomicroscope and a microscope in the laboratory, while additional identifications were made from photographs. Species identified through photographs or on-site were generally ascidians. Taxonomic keys and expert knowledge were used to identify specimens to the lowest feasible taxonomic level. The nomenclature of identified species was verified according to the World Register of Marine Species (WoRMS Editorial Board, 2024).

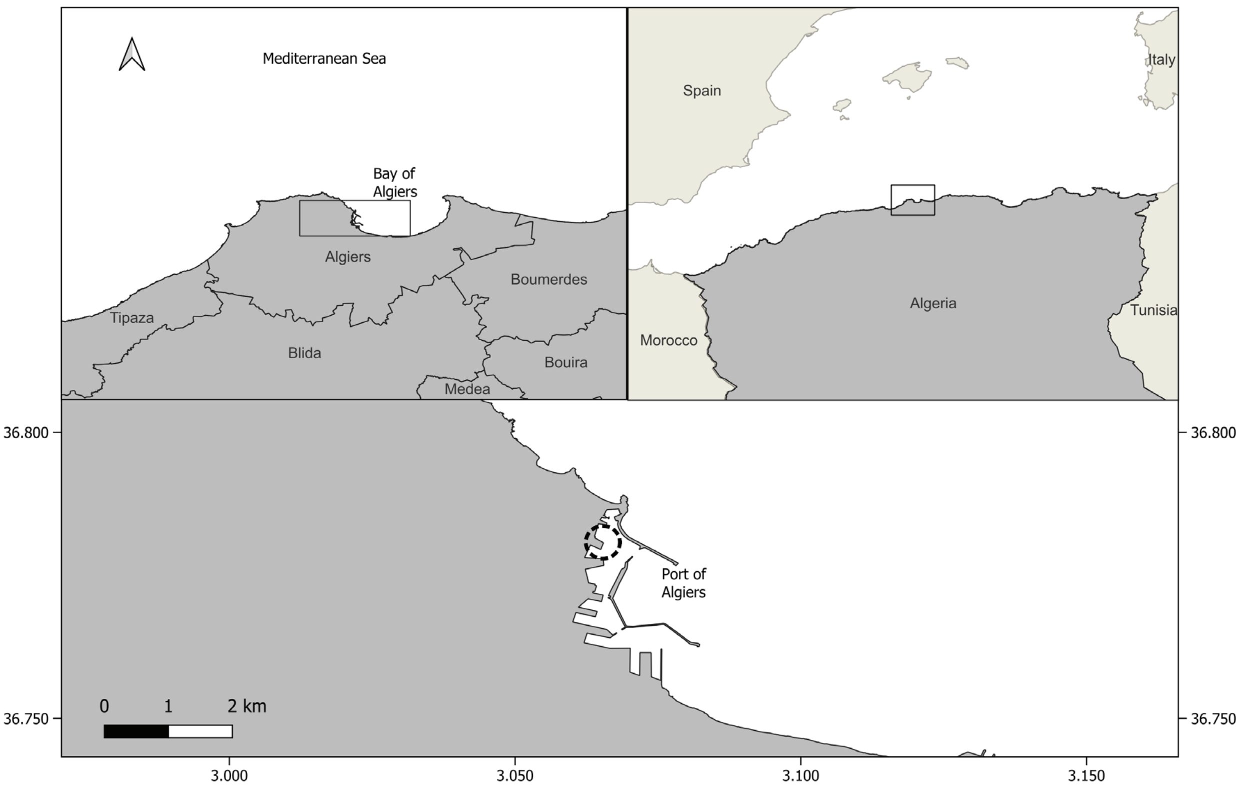

Fig. 1: Location of the study site (area outlined with dashed lines) within the Port of Algiers.

Table 1. Location and characteristics of sampling stations.

Station	Coordinates	Substrate	Dates
Station 1	36.78305° N, 3.06427° E	Tire	29/04/2021
Station 2	36.78306° N, 3.06427° E	Rope	
Station 3	36.78329° N, 3.06434° E	Tire	09/05/2022
Station 4	36.78334° N, 3.06436° E	Rope	
Station 5	36.78363° N, 3.06445° E	Tire	26/05/2023
Station 6	36.78362° N, 3.06445° E	Rope	
Station 7	36.78488° N, 3.06549° E	Dock Post	
Station 8	36.78348° N, 3.06441° E	Quay	14/09/2024
Station 9	36.78401° N, 3.06603° E	Tire	

Results

We identified 18 non-indigenous species within the Port of Algiers. Among these, 13 are certainly non-native to the Mediterranean Sea, while five are classified as cryptogenic (Carlton, 1996), meaning their origins remain uncertain (Table 2, Figs. 2 and 3). Remarkably, 11 of these species are documented here for the first time on the Algerian coastline. Ascidiacea comprise the largest group with six species, followed by Bryozoa with five species. Crustacea and Polychaeta each include three species, while Porifera is represented by one species.

Ascidiacea

Botrylloides *cf.* niger *Herdman, 1886*

Botrylloides niger is a cosmopolitan colonial tunicate commonly found in tropical and warm water regions. In the Caribbean region, its distribution is nearly uniform, and its genetic diversity is highest, suggesting that it may be native to this region (Sheets *et al.*, 2016). Part of the uncertainty surrounding its origin and distribution arises from its taxonomic confusion with similar species. In the Mediterranean, the species is confirmed in Italy (Della Sala *et al.*, 2022), Turkey (Temiz *et al.*, 2023), and Egypt (Halim & Abdel Messeih, 2016). However, in Spain (Carmona-Rodríguez *et al.*, 2024) and Tunisia (Mnasri-Afifi *et al.*, 2024), it was reported as *B.* cf. *niger*, indicating uncertainty in its identification. In Morocco (Mghili *et al.*, 2024), its presence remains questionable. Its distribution in the Mediterranean is likely more extensive, as it is often confused with *Botrylloides leachii* (Savigny). On the iNaturalist platform (consulted on 8 November 2024), this species has been observed 210 times by 30 different observers in the Mediterranean. These observations include sightings in Spain (including Palma), Morocco, Algeria, France, Italy (including Sardinia), Tunisia, Malta, Albania, Greece, and Cyprus.

Almost all specimens photographed closely resemble the "orange-brown" morphotype described by Temiz *et al.* (2023). We identified two morphotypes, the "orange-brown" and the "orange", with the former being the most abundant (Fig. 3D). Additionally, this species exhibited a very high coverage rate. Since 2021, it has been observed at Alger Plage on the eastern side of the Bay of Algiers (personal observation).

Botrylloides *cf.* violaceus *Oka, 1927*

Botrylloides violaceus, first described in Japan in 1927, is native to the Northwest Pacific region, from northern Japan to southern Korea and northern China (Rho *et al.*, 2000). It is now more widely reported in the Northeast Pacific and the North Atlantic (Bock *et al.*, 2011). This colonial tunicate predominantly inhabits artificial substrates such as dock floats, pilings, piers, aquaculture structures, and boat hulls (Simkanin *et al.*, 2012).

Table 2. Non-Indigenous and Cryptogenic Marine Species Identified in the Port of Algiers: First Record, Abundance, Coordinates, and Substrate. **Cat**: Category**, NIS:** Non-Indigenous Species**, DOFF:** date of first found, **Cry:** Cryptogenic **Q**: Quay, **R:** Rope, **T:** Tire, **D:** Dock post.

Taxonomic group	Species	Cat	DOFF	Abun	Coordinates	Substrat			
						Q	R	T	D
Ascidiacea	*Botrylloides* niger	NIS	29/04/2021	High	36.78305° N, 3.06427° E	+	+	+	+
	Botrylloides violaceus	NIS	26/05/2023	Medium	36.78488° N, 3.06549° E	+	+		+
	Botryllus S chlosseri	Cryp	29/04/2021	HIgh	36.78305° N, 3.06427° E	+	+	+	+
	Polyclinum constellatum	NIS	14/09/2024	Medium	36.78348° N, 3.06441° E	+	-	-	-
	Styela canopus	Cryp	14/09/2024	Low	36.78401° N, 3.06603° E	+	-	+	-
	Styela plicata	NIS	29/04/2021	High	36.78305° N, 3.06427° E	+	+	+	-
Bryozoa	*Bugula neritina*	Cryp	29/04/2021	High	36.78305° N, 3.06427° E	+	+	+	+
	Bugulina stolonifera	Cryp	29/04/2021	Low	36.78305° N, 3.06427° E	+	-	+	-
	Celleporaria brunnea	NIS	26/05/2023	Low	36.78363° N, 3.06445° E	-	-	+	-
	Schizoporella errata	Cryp	09/05/2022	High	36.78305° N, 3.06427° E	+	-	+	-
	Tricellaria inopinata	NIS	29/04/2021	Medium	36.78305° N, 3.06427° E	-	-	+	+
Crustacea	*Balanus trigonus*	NIS	14/09/2024	Medium	36.78401° N, 3.06603° E	-	-	+	-
	Jassa slatteryi	Cryp	29/04/2021	Low	36.78305° N, 3.06427° E	-	-	+	-
	Zeuxo coralensis	NIS	29/04/2021	Low	36.78305° N, 3.06427° E	-	-	+	-
Polychaeta	*Branchiomma bairdi*	NIS	29/04/2021	High	36.78305° N, 3.06427° E	+	+	+	-
	Branchiomma luctuosom	NIS	29/04/2021	High	36.78305° N, 3.06427° E	+	+	+	-
	Hydroides elegans	NIS	29/04/2021	High	36.78305° N, 3.06427° E	+	+	+	-
Porifera	*Paraleucilla magna*	NIS	29/04/2021	High	36.78305° N, 3.06427° E	+	+	+	+

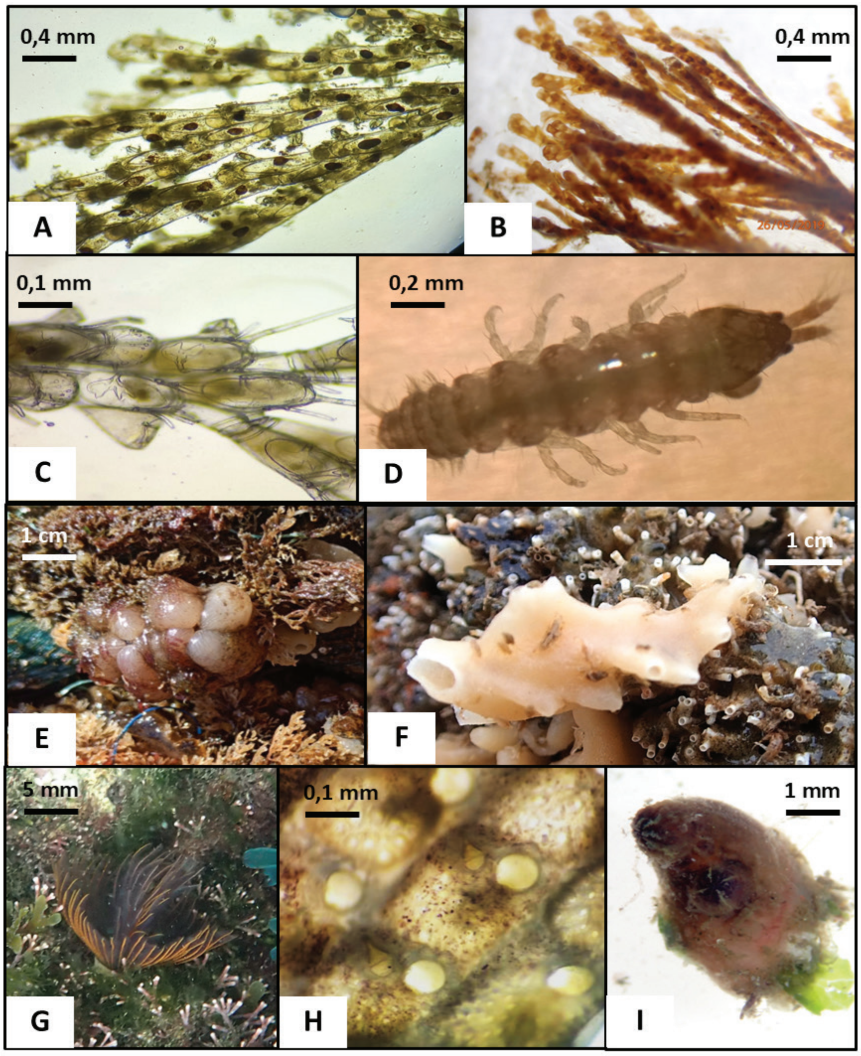

Fig. 2: NIS and cryptogenic species found in this study. A: *Bugulina stolonifera*, B: *Bugula neritina*, C: *Tricellaria inopinata*, D: *Zeuxo coralensis*, E: *Styela plicata*, F: *Paraleucila magna*, G: *Branchiomma luctuosom*, H: *Schizoporella errata*, I: *Styela canopus.*

In the Mediterranean, this ascidian was first collected in 1993 in the Venetian Lagoon (Zaniolo *et al.*, 1998). Since its first record, it was reported Lake Faro and in Messina, Italy (Palanisamy *et al.*, 2018), as well as in France without a specified location (Massé *et al.*, 2023). This is the first report of this species in Algeria (Fig. 3B).

Botryllus schlosseri *(Pallas, 1766)*

The tunicate *B. schlosseri*, which is globally distributed and exhibits significant polymorphism in colour pattern and colony shape, is considered cryptogenic in the Mediterranean Sea (Zenetos *et al.*, 2017). According to recent genetic studies, this species has a Mediterranean origin, as the data reveals the presence of five genetically divergent clades in the region. Europe and the Mediterranean are the most diverse regions, where all clades are present, whereas only one clade is found worldwide (Bock *et al.*, 2012; López-Legentil *et al.*, 2006). One possible cause of this complicated taxonomic situation may arise from the fact that most of the findings come from port areas. Ports and marinas are containment zones where very few fouling species venture beyond. Since they are transported by ships and boats via hulls, there has been greater genetic mixing between Mediterranean ports and marinas due to their higher connectivity compared to other global ports. Moreover, the Mediterranean is a very active region for recreational boating and maritime transport, especially considering its small surface area compared to other oceans (Carreño & Lloret, 2021). This species has been reported in Algeria in the Port of Arzew (Bensari *et al.*, 2020). In our study, *B. schlosseri* was very abundant (Fig. 3C).

Polyclinum constellatum *Savigny, 1816*

The ascidian *P. constellatum,* first described from specimens collected in Mauritius (Indian Ocean), has a pantropical distribution with a wide range of occurrences across various biogeographic regions (Montesanto *et al.*, 2022). In the Mediterranean, it was first recorded in Egypt (Halim & Abdel Messeih, 2016) and has since been observed in Turkey (Aydin Onen, 2018), Italy, and Greece (Montesanto *et al.*, 2022). This species has likely

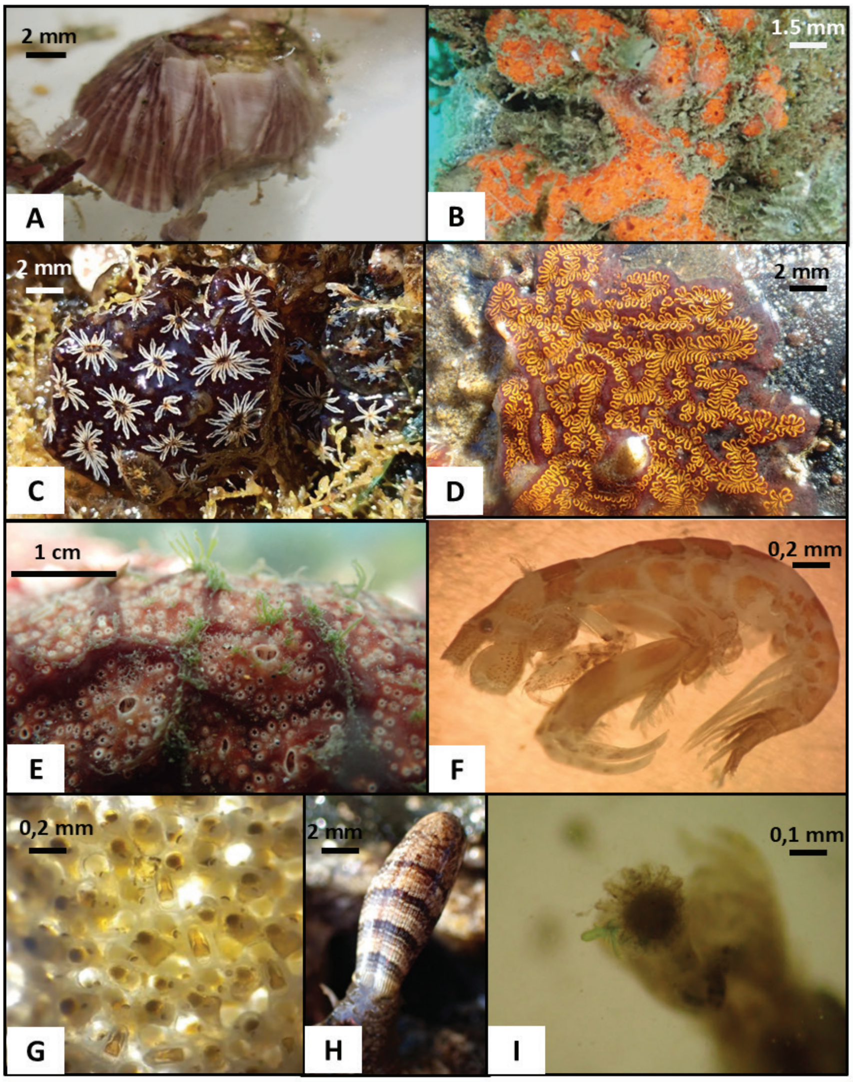

Fig. 3: NIS and cryptogenic species found in this study. A: *Balanus trigonus*, B: *Botrylloides* cf. *violaceus*, C: *Botryllus schlosseri*, D: *Botrylloides* cf. *niger*, E: *Polyclinum constellatum*, F: *Jassa slatteryi*, G: *Celleporaria brunnea*, H: *Branchuiomma bairdi*, I: *Hydroides elegans*.

spread through a Lessepsian migration route (Halim & Abdel Messeih, 2016). In our study, we report *P. constellatum* for the first time in the western Mediterranean (Fig. 3E). This introduction is most likely due to hull fouling on ships, as there is no clear continuity in its expansion from Egypt to Algeria, further supported by the fact that it is a lecithotrophic larval species. We found this species was abundantly attached to the port dock.

Styela canopus *(Savigny, 1816)*

The Rough Sea Squirt, *S. canopus*, is broadly distributed across temperate and tropical coastal waters worldwide (Lambert, 2001). This species was first described in the Red Sea in 1816 and was later documented on both sides of the North Atlantic, at Ascension Island in the South Atlantic, in the Northwest Pacific, throughout the tropical Indo-Pacific, and in the temperate waters of Australia (Kott, 1985). It was reported from the Mediterranean [as *Styela canopoides* (Heller)] in 1877 (Heller, 1877). Its long-standing presence in the Mediterranean and other regions has led to its classification as a cryptogenic species. A genetic analysis of several populations revealed the presence of multiple species (Corrêa de Barros & Moreira da Rocha, 2021). The authors of this study suggested treating *S. canopus* as a species complex. Our study reports this species for the first time in Algeria (Fig. 2I). It was not very frequent in the Port of Algiers.

Styela plicata *(Lesueur, 1823)*

This species is a well-known, cosmopolitan fouling species found in shallow, sheltered areas of tropical and warm-temperate oceans (Ulman *et al.*, 2017). Genetic analysis indicates that its broad geographic distribution is due to numerous introductions caused by human-mediated hull fouling, leading to multiple introduction events (Locke *et al.*, 2009). Furthermore, most sightings are from artificial substrates or harbours, reinforcing the hypothesis of an ongoing invasion. Consequently, it is challenging to determine the exact origin of this species due to these multiple introductions (Locke *et al.,* 2009). However, according to Locke *et al.* (2009), the most probable origin of this species is the Western Pacific. It has been found in the Mediterranean since the 19th century (Zenetos & Galanidi, 2020); we report it in Algeria for the first time (Fig. 2E). It is highly likely that this species was established a long time ago along the Algerian coast, but due to a lack of specialists and insufficient investigation, it has not been reported until now. A related species, *Styela plicata* Lesuer, was observed negatively impacting the growth of cultured bivalves in Brazil, Hong Kong, Japan, and Spain (Rocha *et al.,* 2009).

Bryozoa

Bugula neritina *(Linnaeus, 1758)*

The bryozoan *B. neritina*, a well-known fouling organism, is widely spread along warm-temperate coasts and subtropical regions worldwide (Ryland *et al.*, 2011). Due to its long-standing broad distribution, determining the precisee origin of this species remains challenging; therefore, it is considered cryptogenic in the Mediterranean (Zenetos *et al.*, 2017), where it is widely distributed in the eastern and western basins. In Algeria, *B. neritina* was overlooked in bryozoan studies and is absent from the bryozoan inventory compiled by d'Hondt & Ben Ismail (2008). It was first reported in Algeria in 2020 (Bensari *et al.,* 2020), although it is likely that it has been present for a much longer period. We found the species to be quite abundant in the Port of ALgiers (Fig. 2B).

Bugulina stolonifera *(Ryland, 1960)*

The erect bryozoan *B. stolonifera* is commonly found in ports worldwide, including in the Atlantic and Pacific Oceans, as well as in the Mediterranean (Ryland *et al.*, 2011). It was first described by Ryland (1960) based on samples collected from the port at Swansea, Great Britain, and older specimens from an herbarium acquired by the British Museum. These specimens, dating back to before 1875, were labeled "British coast". The origin of this species remains unknown due to its long-standing confusion with other species such as *Bugulina spicata* (Hincks), *Bugulina avicularia* (Linnaeus), and *Crisularia pulmosa* (Pallas) (Bensari *et al.*, 2020). Additionally, its broad distribution across the globe occurred so long ago that tracking its geographical dispersal is challenging. In Algeria, this species was recorded for the first time in the Port of Arzew (Bensari *et al.,* 2020). In the Port of Algiers, *B. stolonifera* was not frequently observed (Fig. 2A).

Celleporaria brunnea *(Hincks, 1884)*

This bryozoan was described by Hincks in 1884 as *Cellepora brunnea* from British Columbia, Canada (Canning-Clode *et al.*, 2013). It is naturally found in fouling communities along the northeastern Pacific coasts, ranging from British Columbia to Ecuador (Lezzi *et al.,* 2015). In 2004, *C. brunnea* was found on aquaculture steel cages in South Korea, where it was believed to have been introduced from the eastern Pacific Ocean (Seo & Min, 2009). This species is also found in the northeastern Atlantic in Portugal (Canning-Clode *et al.*, 2013), including the Maderia Archipelago (Souto *et al.*, 2023), France (André *et al.,* 2014), and Norway (Husa *et al.*, 2024). In the Mediterranean, it is found in Lebanon, Italy, Croatia, Turkey, France, Malta, and Greece (Ulman *et al.*, 2017). We document *C. brunnea* in Algeria for the first time (Fig. 3G). It was observed infrequently during the period of this study.

Schizoporella errata *(Waters, 1878)*

This bryozoan is a widely distributed species found in warm temperate and subtropical regions (Tilbrook *et al.*, 2001). First described from Naples, Italy, it occurs throughout the Mediterranean, West Africa, eastern Canada, the eastern coasts of the Americas from North Carolina through the Caribbean to Brazil, the Pacific coast of North America, the Red Sea, the Persian Gulf, southern Australia, and New Zealand (Tilbrook *et al.*, 2001). Its origin has long been presumed to be the Mediterranean due to its ancient presence in the basin. However, the global distribution of this species challenges the notion of a Mediterranean origin, as it could have been introduced there before the 19th century. It is now considered cryptogenic in the Mediterranean (Katsanevakis *et al.*, 2020). D'Hondt & Ben Ismail (2008) mentioned that the species was reported by Gautier (1955) in Algeria. However, after thoroughly reviewing all of Gautier's references, including the one from 1955, we found no mention of this species. Hence, our observation (Fig. 2H) in the Port of Algiers constitutes the first record of *S. errata* in Algeria.

Tricellaria inopinata *d'Hondt & Occhipinti Ambrogi, 1985*

This bryozoan was described from the Venetian Lagoon (d'Hondt & Occhipinti Ambrogi, 1985), but its origin is not Mediterranean. It is potentially from the Indo-Pacific Ocean, as the genus *Tricellaria* is typical of this ocean (Dyrynda *et al.*, 2000). Indeed, specimens of *Tricellaria* washed ashore in central Oregon in 2012 on debris from the 2011 Japanese tsunami and were identified as *T. inopinata*, suggesting Japan as its native region (McCuller & Carlton, 2018). This species is present in the northeastern Atlantic, ranging from Germany to Spain, as well as along the British and Irish coasts (Cook *et al.,* 2013) and the coast of Norway (Porter *et al.*, 2015). In the Northwest Atlantic, after its first discovery in Eel Pond, Massachusetts (Johnson *et al.*, 2012), *T. inopinata* expanded its range to the Hampton River in New Hampshire (Wells *et al.*, 2013). In the Mediterranean, it is present in Italy (Lodola *et al.*, 2012), Tunisia (Ben Souissi *et al.*, 2006), France, and Greece (Ulman *et al.*, 2017). The impact of this species is significant, as it dominates benthic communities and outcompetes other sessile species for space and food (Tsirintanis *et al*., 2022). Our encounter of it the Port of Algiers marks the first reported occurrence of this species in Algeria (Fig. 2C), where we found it infrequently.

Crustacea

Balanus trigonus *Darwin, 1854*

Balanus trigonus, commonly called the triangle barnacle, was originally described based on specimens collected from the Pacific region, including Indonesia, Colombia, Peru, Australia, and New Zealand (Darwin, 1854). This barnacle has a global distribution and is considered introduced in the Atlantic Ocean and the Mediterranean Sea (Zullo, 1992). Its first record in the Mediterranean dates to 1927 in the Gulf of Catania, Italy (Zullo, 1992), and it is now widespread across the entire Mediterranean basin (Galanidi *et al*., 2023). Our observation of it at the Port of Algiers is the first record of this species on the Algerian coast (Fig. 3A), but it is highly likely that was introduced well before. During our sampling, several specimens were found on a tire.

Jassa slatteryi *Conlan, 1990*

The amphipod *J. slatteryi*, likely native to the eastern Pacific, has an uncertain origin and is considered cryptogenic in other regions, including the Mediterranean, as the species has been misidentified multiple times, leaving its true native and introduced distribution still to be determined (Marchini & Cardeccia, 2017). In a comprehensive study of the genus *Jassa*, Conlan *et al.* (2021) suggested a northeastern Pacific origin for the species, as it is found in artificial and natural habitats in that region, and because the species was never recorded on the European coast before 1900, a zone with over 200 years of natural history collecting. According to Pilgrim & Darling (2010), who found as much genetic variability in *J. slatteryi* as in the native eastern Pacific *Jassa staudei* Conlan, suggesting that *J. slatteryi* is also native to this region. A more recent study based on the genetic analysis of several specimens from various regions suggests that the species has a North Pacific origin (Beermann *et al.,* 2020). Recently, Bakalem *et al.* (2024) classified it as non-indigenous to the Mediterranean, based on the species was not reported in the region before 1997 by Ruffo (1982, 1989, 1993, 1998). Bonifazi *et al.* (2018) cited Conlan (1990) to claim that the species was first observed in Croatia. However, upon consulting Conlan (1990), no reference to Croatia was found. Instead, the species was reported from “Cette”, an old spelling of the city of Sète in the Mediterranean region of France (K. E. Conlan, personal communication). Further examination of her archival notes revealed that the specimen originally identified was not *J. slatteryi* but rather *Jassa morinoi* Conlan. Consequently, it is *J. morinoi* that was cited from Sète, and there is no evidence to suggest that *J. slatteryi* has been recorded in the Mediterranean. Based on this evidence, we suggest that the status of this species should be considered non-indigenous. It is worth noting that this species was observed in the port of Ceuta with a very high relative abundance and has been classified as having a high invasion potential (Ros *et al.*, 2020). Our finding of it in the Port of Algiers documents the occurrence of *J. slatteryi* in Algeria for the first time (Fig. 3F). We found the species to be not very frequent in our observations.

Zeuxo coralensis *Sieg, 1980*

The tanaidacean *Zeuxo coralensis* has a circumtropical distribution (Masunari & Sieg, 1980). In the Mediterranean Sea, it was first discovered in the Bay of Algeciras (southern Spain) between 1992 and 1993 on artificial and natural substrates (Sánchez-Moyano & García-Gómez, 1998). The species has also been encountered in the eastern Mediterranean (Zenetos *et al.*, 2010). *Zeuxo coralensis* was observed for the first time in Algeria at the Port of Arzew (Bensari *et al.*, 2020). We found *Z. coralensis* on a tire (Fig. 2D).

Polychaeta

Branchiomma bairdi *(McIntosh, 1885)*

The tube-dwelling sabellid *B. bairdi* was first described from Bermuda and is known from central Florida to the Atlantic side of Panama and the Caribbean Islands (Tovar-Hernández *et al.*, 2009). This species was later introduced to the Gulf of California and Hawaii. It has also been introduced to the Mediterranean Sea, the Canary Islands, the Balearic Sea, Madeira (Portugal), Queensland (Australia), the Pacific coast of Mexico, and Coiba National Park in the Gulf of Montijo on the Pacific coast of Panama (Keppel *et al.*, 2018). The initial introduction of this species into the Mediterranean remains uncertain due to frequent misidentification with *Branchiomma boholense* (Grube). However, the first confirmed report of this species was in Cyprus (Çinar, 2005 as *B. boholense*, later re-examined and correctly identified as *B. bairdi* in Çinar, 2009). *Branchiomma bairdi* was also observed in Tunisia in 2012 (Khedhri *et al.*, 2017). We document *B. bairdi* in Algeria for the first time (Fig. 3H), and our observations indicate that the species is highly abundant.

Branchiomma luctuosum *(Grube, 1870)*

Branchioma luctuosum, first described in the Indo-Pacific region, was likely introduced to the Mediterranean through the Suez Canal (Licciano & Giangrande, 2008). Following its initial discovery in Italy in 1978 (Knight-Jones *et al.*, 1991), *B. luctuosum* has rapidly spread throughout the Mediterranean and is now widely distributed in the region (Mabrouki & Taybi, 2024), particularly in the northern part. Our encounter of *B. luctuosum* (Fig. 2G) is a new country record for Algeria, where it is well established in the Port of Algiers. Additionally, this species has been observed at Bordj El Bahri to the east of Algiers Bay (personal observation), with a very high density on hard substrates in the infralittoral zone.

Hydroides elegans *(Haswell, 1883)*

The serpulid *H. elegans* seems to be a circumtropical species that extends into warm-temperate zones and is considered an alien species in the Mediterranean Sea, likely introduced via ship hulls (Zibrowius, 1991). This species is established in the entire Mediterranean basin and is considered long-standing resident (Zenetos *et al.*, 2012). It is considered invasive due to significant impact on biodiversity and ecosystem services (Katsanevakis *et al.*, 2014). *Hydroides elegans* (Fig. 3I) was first reported in Algeria at the Port of Algiers, but its presence along the Algerian coast is likely much older. In the Port of Arzew (Oran), Bensari *et al*. (2020) found the species to be as abundant as in this study.

Porifera

Paraleucilla magna *Klautau, Monteiro, & Borojevic, 2004*

This calcareous sponge was described from the Brazilian coast where it was considered cryptogenic (Klautau *et al.,* 2004). The origin of this species remains unknown but is likely Indo-Pacific, as is the origin of most species in the genus *Paraleucilla* (Longo *et al.*, 2007). In the Mediterranean, *P. magna* is considered non-indigenous and has rapidly spread to several locations. It is now widespread throughout the Mediterranean (see Katsanevakis *et al.*, 2020 for a more detailed distribution). Its rapid spread is attributed to mussel farming as well as maritime traffic (Longo *et al.*, 2007). Molecular study of samples collected from the Atlantic coast of Brazil and the Adriatic Sea suggests the presence of five genetically distinct populations, likely originating from multiple human-mediated introductions from various sources (Cavalcanti *et al.*, 2020). *Paraleucilla magna* (Fig. 2C) was first observed in Algeria in 2018 simultaneously at several locations, including the Port of Algiers, Pisan Island (Béjaia) (Bachetarzi *et al.*, 2019), and the Port of Arzew (Oran) (Bensari *et al.*, 2020). This suggests that the species may have been introduced some time ago, especially considering its presence on Pisan Island, a location distant from any direct anthropogenic activities likely to lead to an introduction.

Discussion

While several species identified in this study are documented here for the first time in Algeria, their introductions likely date back many years, considering the historical significance of the Port of Algiers as one of the oldest in the Mediterranean. Notably, *S. plicata*, *H. elegans*, *B. schlosseri*, *C. brunnea*, and *B. bairdi* rank among the most reported non-native species in ports throughout the Mediterranean region (Tempesti *et al.*, 2020).

The 18 species identified in this study underscores our limited understanding of non-indigenous species along the Algerian coast, a reality that is similarly reflected across several Mediterranean countries (Ulman *et al.*, 2017) due to a lack of taxonomic expertise or lack of focused inventories. Other species may be present but were missed because it was not possible to identify all taxa due to limited taxonomic expertise, and sampling was restricted in terms of area, depth, and substrate type.

Maritime transport has played a significant role in the transfer of exotic species between different geographic regions, whether directly from their native ranges or through secondary introductions from other Mediterranean areas. Hull fouling is undoubtedly the most important vector of introduction of the species we observed, as most of these species are biofouling organisms. Moreover, hull fouling is the only viable transport method for species with short lecithotrophic larval stages, such as ascidians. Maritime transport is a vital pathway for secondary introductions, dispersing species across regions through the interconnected network of Mediterranean ports – with even pleasure boats playing a significant role in this process. Ships carry introduced species from one port to another, facilitating their dispersal. For instance, *P. constellatum*, likely a Lessepsian migrant, has established itself in the Mediterranean and was discovered in the Port of Algiers in our study. Its occurrence in the port is most likely due to a secondary introduction originating from the eastern Mediterranean.

The question of the origin of non-indigenous species remains complex for several reasons. On the one hand, these species are often attributed to the Mediterranean or other regions simply because they were first described there –although they were likely widespread long before the 20th century– due, in part, to more intensive sampling of the Northern Hemisphere, especially along European coasts. On the other hand, taxonomic difficulties, particularly for fouling species that are often cosmopolitan and may belong to species complexes, add an additional layer of complexity. This ambiguity highlights the need for historical data, improved taxonomic research, and molecular techniques to more accurately trace the biogeographical history of these organisms and determine their true origins, even though pinpointing an exact origin remains challenging in many cases.

One key question to take away from our study is which species are most likely to spread beyond the port environment. Among the species we encountered, it is evident that *B.* cf *niger* and *B. luctuosum*, which are widely distributed across Algeria, warrant serious study to assess their impact on native species. For example, based on our own observations outside the port of Algiers, we have noted that *B. luctuosum* is particularly prevalent.

Our study represents a valuable contribution to the enrichment of data and information on non-indigenous species in port environments in the Mediterranean. It highlights the Algerian coast, a region where information remains scarce, and its results offer insights that bridge knowledge gaps and support future research.

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