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First records of non-indigenous species in port of Arzew (Algeria: southwestern Mediterranean)

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Abstract

Maritime transport is considered to be one of the main causes of transfer of non-indigenous species (NIS), through biofouling of ships' hulls and ballast water. Ports and marinas constitute hot spots for the introduction of species carried by international shipping and therefore are important sites for initiating biological monitoring. In this study, the port of Arzew (Algeria, Southern Mediterranean) was surveyed for the presence of NIS and cryptogenic species. The fouling communities of floating submerged structures and the hull of a fishing vessel were sampled with a scraper blade. After fixing and separating, the organisms were identified to the lowest possible taxonomic level. The results revealed the presence of 10 NIS and cryptogenic species, including: 1 Ascidiacea, 2 Bryozoa, 3 Crustacea, 1 Mollusca, 1 Porifera, and 2 Polychaeta. Five species are reported for the first time from the Algerian coast. This study contributes to the knowledge of non-native species on the Algerian coast and in the Southern Mediterranean and establishes a baseline dataset for future assessments of NIS in ports of Algeria.

Keywords: Alien species; Cryptogenic species; Fouling communities; Algerian coast; Maritime transport.

Introduction

Marine biological invasions are considered one of the most important direct drivers of biodiversity loss and have a serious impact on ecosystem services (Katsanevakis *et al.*, 2014). The Mediterranean Sea is one of the marine basins most affected by such invasions, fostered by the opening of the Suez Canal, intense maritime traffic, aquaculture, and the aquarium trade (Streftaris *et al.*, 2006; Galil, 2009).

Maritime transport appears to be the main cause of transfer of NIS, through biofouling of ship hulls and ballast water (Gollasch, 2002; Bouda *et al*., 2018). In the West Mediterranean, shipping remains the most prominent route for these introductions (Zenetos *et al.,* 2012). Therefore, ports and marinas constitute an important site for the introduction of species carried by international shipping (Ulman *et al.,* 2017).

Docks and floating objects in ports provide solid surfaces characterized by continuous immersion at a constant, shallow depth, thus providing protection from the seabed's predators. Such surfaces support an abundant fouling biota and appear to favour NIS (Neves *et al.,* 2007; Glasby *et al.,* 2007). Therefore, ports are important sites for initiating biological monitoring (Awad *et al.,* 2014).

In the Mediterranean, as in many parts of the world, many ports and marinas have been surveyed for the presence of NIS. However, such monitoring is rare in the southern Mediterranean compared to the north. Among these rare studies, we cite the monitoring of the marinas of El Kantaoui and Cap Monastir (Tunisia) and El Alamein (Egypt) (Sghaier *et al.,* 2019).

In Algeria, only two studies have investigated the biodiversity in ports (Rebzani-Zahaf, 2003; Grimes, 2010), targeting the soft substrate macrozoobenthos. The port of Arzew is the most important port in Algeria. Bouda *et al.* (2016; 2018) conducted a theoretical risk assessment of species introduction by ballast water and biofouling on ship hulls (as an indicator of the importance of propagule pressure) and demonstrated that the port of Arzew is vulnerable to new introductions. However, there is a lack of data on the presence of non-native species in this port.

This study aimed to: (i) assess for the first time the presence of NIS in the port of Arzew, which is considered the most important port in Algeria; (ii) contribute to the

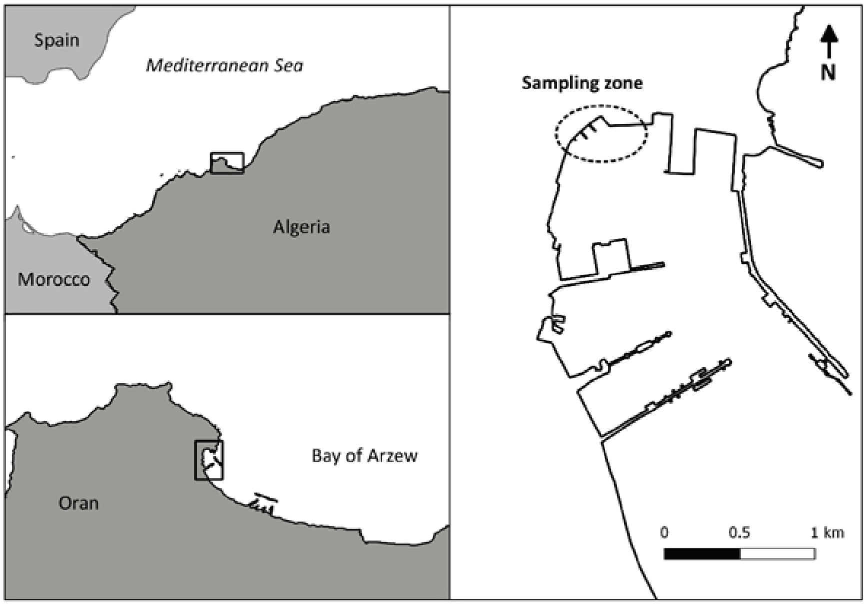

Fig. 1: Location of the Port of Arzew in Algeria. The sampling zone is indicated with a dotted line circle.

knowledge of non-native species on the Algerian coast and in the Southern Mediterranean; and (iii) establish a baseline dataset for future assessments of NIS in Algerian ports.

Material and Methods

Study area

The port of Arzew (Fig. 1) is located east of Cape Carbon in Arzew Bay, at 350 km west of Algiers and 500 km east of the Strait of Gibraltar. It is principally used for the export of hydrocarbons, and to a lesser extent for trade and fisheries. This implies that most boats systematically unload their ballast water during the loading operation and thus large quantities of ballast water originating from other ports around the world are discharged at the port of Arzew (Bouda *et al.,* 2016). Therefore, the risk of species introduction is very high. According to the report of the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC, 2008), the port of Arzew was classified as one of the Mediterranean ports most vulnerable to this type of risk. Biofouling constitutes an additional risk for the introduction of NIS (Bouda *et al.,* 2018).

Sampling

Sampling was performed in two periods, early winter (December 2018) and spring (April 2019). Given that Arzew is mainly an oil and gas port and due to restrictions imposed by the port authorities, sampling focused only on floating structures (e.g. mooring buoys and tires used for berthing protection and ropes) and on the hull of a fishing vessel. Careful scraping was performed using a blade, in a way that allowed for the identification of taxa and the estimation of abundance (low or high). All samples were carefully stored in collecting bags and were immediately fixed with formalin (4–5%). In the laboratory, samples were sieved through a 1 mm mesh. All animals were sorted and identified to the lowest possible taxonomic level. Photographs and videos of fouling communities were also taken. The taxonomic nomenclature of all identified species was verified according to the World Register of Marine Species (WoRMS Editorial Board, 2020).

Results and Discussion

A total of 10 NIS and cryptogenic species were identified in the port of Arzew (Table 1, Fig. 2), including: 1 Ascidiacea, 2 Bryozoa, 3 Crustacea, 1 Mollusca, 1 Porifera, and 2 Polychaeta. Five of these species are reported for the first time on the Algerian coast; 4 are considered as cryptogenic, 6 aliens (1 casual and 5 established).

Botryllus schlosseri (Pallas, 1766)

According to Zenetos *et al.* (2017), the tunicate *Botryllus schlosseri*, which is distributed worldwide and shows marked polymorphism in chromatic patterns and colony shapes, is considered cryptogenic for the Mediterranean Sea. It has been shown that the taxon *B. schlosseri* is a complex of five genetically differentiated species (Lopez-Legentil *et al.,* 2006; Bock et *al.,* 2012) and all are present in the Mediterranean. Regarding the origin of this species, two theories should be noted. The first theory considers that the ascidian originated from the Mediterranean and spread around the world with shipping (Berril, 1950; Carver *et al.,* 2006); the second theory is that *B. schlosseri* may have been introduced to Europe as early as the 1500s from the Pacific Ocean, the centre

Table 1. Marine NIS and cryptogenic species recorded in the port of Arzew (Algeria). YFSA = Year of First Sighting in Algeria, est = established, cas = casual, cry = cryptogenic, al: alien.

	Origin	YFSA	Source	Status
Ascidiacea				
Botryllus schlosseri (Pallas, 1766)	Mediterranean ?	Present Study		cry
Bryozoa				
Bugula neritina (Linnaeus, 1758)	Unknown	Present study		cry
Bugulina stolonifera (Ryland, 1960)	Unknown	<1955	Gautier (1955)	cry
Crustacea				
Elasmopus pectenicrus (Spence Bate, 1862)	Circumtropical	1984-1986	Bakalem and Dauvin (1992)	cry
Zeuxo coralensis Sieg, 1980	Circumtropical	Present Study		al/est
Paracerceis sculpta (Holmes, 1904)	NE Pacific	Present Study		al/est
Mollusca				
Godiva quadricolor (Barnard, 1927)	East Indian	present study		al/cas
Polychaeta				
Hydroides dirampha Mörch, 1863	East Atlantic	1983	Rebzani-Zahaf (2003)	al/est
Hydroides elegans (Haswell, 1883)	Circumtropical	1983	Rebzani-Zahaf (2003)?	al/est
Porifera				
Paraleucilla magna Klautau, Monteiro & Borojevic, 2004	SW Atlantic ?	2019	Bachetarzi *et al.* (2019)	al/est

of botryllid diversity (Carlton, 2005). Population genetics studies showed the possibility that the Mediterranean is a centre of diversity for *B. schlosseri*, and probably its site of origin (Lejeusne *et al.,* 2011; Reem *et al.,* 2017). In this study, *B. schlosseri* was abundant on almost all sampled structures and was also recorded in the port of Algiers (personal observation, BB).

Bugula neritina (Linnaeus, 1758)

The Bryozoan *Bugula neritina* is a common fouling organism worldwide, and reported from almost all seas. The cosmopolitan distribution of this species is probably due to shipping introductions. According to Coll *et al.* (2010) *B. neritina* has an Indo-Pacific origin and was spread by ships during the 19th and 20th centuries. However, data from a molecular study (Fehlauer-Ale *et al.,* 2014) revealed that *B. neritia* is a complex of three cryptic species, but unfortunately Mediterranean populations were not considered in that study. Therefore, this species will be categorized as a cryptogenic species until more information is available (Zenetos *et al.,* 2017). *B. neritina* is one of the dominant fouling organisms in many Mediterranean harbours (Ramadan *et al.,* 2006; Spagnolo *et al.,* 2019). *B. neritia* was not mentioned in the latest inventory of bryozoans from the Algerian coast (D'Hondt & Ben Ismail, 2008). This is the first report of this species in Algeria. This bryozoan was very abundant in the port of Arzew.

Bugulina stolonifera (Ryland, 1960)

The erect bryozoan *Bugula stolonifera* is widely reported from ports around the world, including the Atlantic and Pacific Oceans and the Mediterranean (Ryland *et al.,* 2011). It was first described by Ryland (1960) in samples taken from the port of Swansea (Great Britain) and from older specimens of a herbarium purchased by the British Museum; these samples dating back to before 1875 are labelled "British coast" but this label is not supported by the record. If this label is correct, the species would clearly not be a recent introduction in Great Britain. According to Ryland (1960), *B. stolonifera* was already present in the Mediterranean (Corsica), where it was confused with *Bugulina spicata* by Calvet (1902). However, the native range of *B. stolonifera* is unclear, especially because this species is easily confused with other species, such as *B. californica* (Cohen & Carlton, 1995), *B. avicularia* and *B. plumosa* (Ryland *et al.,* 2011) and there are no molecular studies to suggest an evolutionary origin. *Bugulina stolonifera* has been reported from Algeria as *B. avicularia* (Gautier, 1955).

Elasmopus pectenicrus (Spence Bate, 1862)

The amphipod *Elasmopus pectenicrus* has a circumtropical distribution: Atlantic Ocean, Red Sea, Indian Ocean, Pacific Ocean (described from New Guinea) (Bellan-Santini *et al.*, 1982). It has long been considered as a Red Sea immigrant, but recent taxonomic studies pointed out that *E. pectenicrus* is actually a group of cryptic species; consequently, it is considered cryptogenic (Marchini & Cardeccia, 2017). *Elasmopus pectenicrus* is found in different habitats such as infralittoral algal communities, shell bottoms and artificial habitats (Zakhama-Sraieb & Charfi-Cheikhrouha, 2010) and fine sandy beds (Bakalem & Dauvin, 1992). A very high abundance associated with hydroid communities on artificial habitats was found in this study. The first observation of this amphipod along the Algerian coast was made in 1989 by Bakalem & Dauvin (1992).

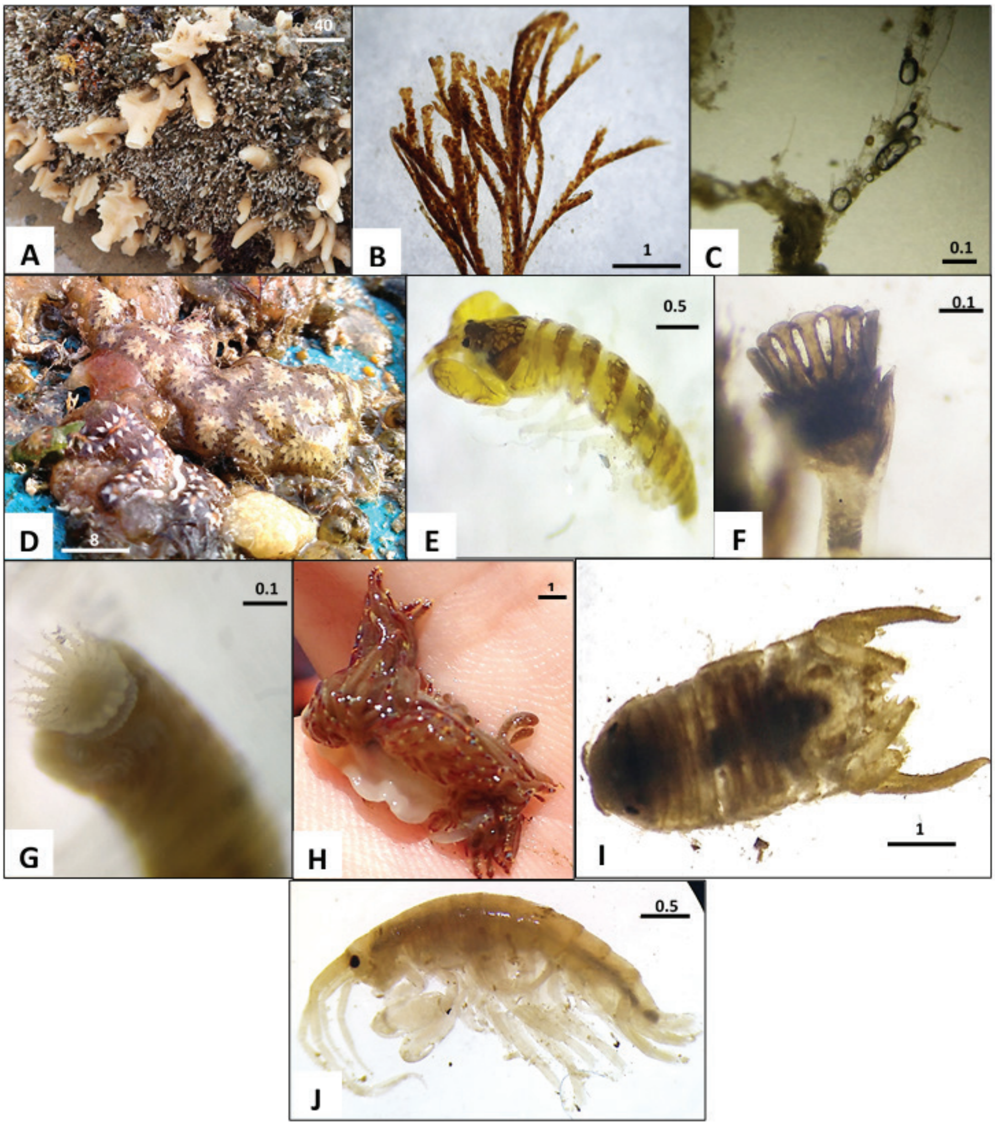

Fig. 2: NIS and cryptogenic species found in the port of Arzew. A: *Paraleucilla magna,* B: *Bugula neritina,* C: *Bugulina stolonifera,* D: *Botryllus schlosseri*, E: *Zeuxo corallensis,* F: Operculum of *Hydroides dirampha,* G: Operculum of *Hydroides elegans,* H: *Godiva quadricolor,* I: *Paracerceis sculpta,* J: *Elasmopus pectenicrus,* All scales in mm

Zeuxo coralensis Sieg, 1980

The tanaidacean *Zeuxo coralensis* has a circumtropical distribution (Masunari & Sieg, 1980). In the Mediterranean Sea it was discovered for the first time in the Bay of Algeciras (South Spain) between 1992 and 1993 on both artificial and natural substrates (Sánchez-Moyano & García-Gómez, 1998) and in the Levantine Seas (Zenetos *et al.,* 2010). In this study *Z. coralensis* was observed on a ship hull and on a tire.

Paracerceis sculpta (Holmes, 1904)

Native to the north-east Pacific, *Pracerceis sculpta* has been recorded in several places, including Hong Kong, Brazil and Australia (Munguia & Shuster, 2013). Its first record in the Mediterranean Sea dates back to 1978 from Tunis (Rezig, 1978). Henceforth, this isopod seems to be present throughout the Mediterranean basin (Zenetos *et al.,* 2010). During our sampling, *P. sculpta* was present on a tire and on the hull of a fishing vessel. This represents the first report of this species in Algeria.

Godiva quadricolor (Barnard, 1927)

The nudibrach was first described from the south African coast in 1927 where it is considered common in shallow waters along the whole east coast of South Africa (Betti *et al.,* 2015). It was always found in *Zostera* meadows or under stones in intertidal areas. Edmunds (1977) reported *Godiva quadricolor* for the first time in the Atlantic Ocean (Ghana) on a boat hull. Also, *G. quadricolor* was reported from Australia (Willan, 1987). The first record of this species in the Mediterranean dates to 1985 in the Gulf of Naples, where it was confused with *Facelina coronata* (Betti *et al.,* 2015). Cervera *et al.* (2010) reported this species in the Bay of Algeciras (Strait of Gibraltar), Betti *et al.* (2015) observed it from the Ligurian Sea and Gerovasileiou *et al.* (2017) from France. In this study, one specimen was found on a rope. Nevertheless, this individual was damaged and quickly began to lose its cerates, but was identified by its numerous blue, yellow and orange striped cerates. It is undoubtedly non-native to the Mediterranean, where it was introduced by maritime transport.

Hydroides dirampha Mörch, 1863

Hydroides dirampha was found twice in the study area, on a tire and on the hull of a boat. It seems that this species originated from the American coast of the tropical Atlantic (Gulf of Mexico, Caribbean, West Indies, Brazil) where it is abundant and not limited to port environments (Zibrowius, 1973). it was recorded for the first time in the Mediterranean Sea at the port of Naples in 1870. Nowadays it is common in the whole Mediterranean basin. *H. dirampha* was reported for the first time in Algeria in 1983 at the port of Algiers as *H. lunulifera* (Rebzani-Zahaf, 2003). Later, Grimes (2010) reported it under the same name without location details.

Hydroides elegans (Haswell, 1883)

Hydroides elegans is a circumtropical species, extending into the warm-temperate zone, and is considered to be an alien species for the Mediterranean Sea, introduced on ship hulls (Zibrowius, 1991). This species was very abundant in the study area, found in dense aggregations on almost all submerged artificial surfaces. High levels of abundance have also been reported from several Mediterranean ports (Zibrowius, 1991; Spagnolo *et al.,* 2019). A comparison of studies on biofouling communities between the years 1960 and 1999 in the Eastern harbour of Alexandria (Ramadan *et al.,* 2006) revealed that the serpulid *H. elegans* was the most dominant species in all studies. The species has previously been reported from Algeria as *Hydroides norvegicus* by Rebzani-Zahaf (2003), who collected it in 1983 at the port of Algiers.

Paraleucilla magna Klautau, Monteiro & Borojevic, 2004

The calcareous sponge *Paraleucilla magna* was first described from Rio de Janeiro, Brazil (Klautau *et al.,* 2004). In the Mediterranean Sea, this species was first identified at four different localities in Italy (Taranto, Porto Cesareo, Brindisi and Naples), and in Spain, Malta, Croatia, Montenegro, Turkey, Cyprus and Greece (for details see Gerovasileiou *et al.,* 2017). Moreover *P. magna* was discovered on the southern shore of the Mediterranean Sea, in Algeria (port of Algiers and Pisan Island of Bejaia) in 2018 (Bachetarzi *et al.,* 2019) and Tunisia (marina of Cap Monastir (Sghaier *et al.,* 2019); port of Bizerte, personal observation). Despite the unknown origin of *P. magna* in the Mediterranean Sea this calcareous sponge is considered a NIS (Zammit *et al.,* 2009). Bivalve aquaculture and shipping are the most probable vectors responsible for its spread. In this study *P. magna* was abundant in the port of Arzew on almost all artificial substrates. Pierri *et al.* (2010) reported that *P. magna* plays a structural role within the studied fouling community in the Mar Piccolo of Taranto (Italy).

Among the species found during this study, it is useful to note the presence of *Hydroides dianthus*, which has long been considered as alien to the Mediterranean and originated from the Atlantic coast of North America. According to a recent molecular study (Sun *et al.,* 2017), the global invader *H. dianthus* seems to have originated from the Mediterranean Sea. It has however been removed from the Mediterranean aliens list of established species (Zenetos *et al.,* 2017).

The number of non-native or cryptogenic species found in this preliminary study greatly underestimates the actual number of non-native species that may be present in the port of Arzew because: (i) it was not possible to identify all taxa due to the lack of taxonomic expertise (e.g. Sipincula, Cirripedia, Polychaeta: Errantia, etc.); (ii) sampling was restricted in terms of area, depth and substrate type; and (iii) the sampled surface was below the minimal sampling area, as suggested by other surveys in Mediterranean port communities (Hewitt & Martin, 2001; Spagnolo *et al.,* 2019).

Indeed, if we compare the number of NIS found during this study (6 species) with the number of non-native species found in 5 Italian ports (Western Mediterranean), the number was clearly lower, as Ferrarion *et al.* (2017) recorded 12 NIS in the port of Genoa, 8 in the port of La Spezia, 11 in the port of Leghorn, 12 in the port of Olbia and 14 in the port of Porto Torres. Three species were found in all of these ports and the port Arzew: *H. dirapmha, H. elegans* and *P. sculpta*.

In the most recent inventory of introduced marine species of Algeria, Grimes *et al.* (2018) listed 39 NIS and 11 cryptogenic species. Although there have been some new reports of NIS from the Algerian coast since this work (e.g. *Callinectes sapidus* (Benabdi *et al.,* 2019), *Paraleucilla magna* (Bachetarzi *et al.,* 2019)), it is probable that the number of NIS in Algeria remains largely underestimated, due to the lack of taxonomists and biomonitoring programmes. Data from this monitoring of ports will provide vital information on the distribution of NIS in Algeria and on the southern Mediterranean coast. This information will serve as a baseline for future monitoring inside and outside Algerian ports.

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References

Awad, A., Haag, F., Anil, A. C., Abdulla, A., 2014. Guidance on Port Biological Baseline Surveys. *Monograph*, 22, 1-57.

Bachetarzi, R., Rebzani-Zahaf, C., Deudero, S., Vázquez-Luis, M., Uriz, M. J. *et al.,* 2019. The non-indigenous and invasive species *Paraleucilla magna* Klautau, Monteiro & Borojevic, 2004 (Porifera: Calcarea) in the Algerian coast (Southwestern of Mediterranean Sea). *Acta Adriatica*, 60 (1), 41-46.

Bakalem, A., Dauvin, J.C., 1992. Sur les Amphipodes d'Algérie. *Mémoires de l'Institut Oceanographique de Monaco*, 13, 364 pp.

Bellan-Santini, D., Karaman, G., Krapp-Schickel, G., Ledoyer, M., Myers, A., *et al.*, 1982. The amphipodes of the mediterranean. I- Gammarides (Acanthonozomatidae to Gammaridae). (Ruffo S. Eds.) *Mémoires de l'Institut Océanographique de Monaco*, 13, 1-364.

Benabdi, M., Belmahi, A.E., Grimes, S., 2019. First record of the Atlantic blue crab Callinectes sapidus Rathbun, 1896 (Decapoda: Brachyura: Portunidae) in Algerian coastal waters (southwestern Mediterranean). *BioInvasions Records,* 8 (1), 119-122.

Berril, N.J., 1950. *The Tunicata, with an account of British species*. Ray Society, London, 354 pp.

Betti, F., Cattaneo-Vietti, R., Bava, S., 2015. Northernmost record of *Godiva quadricolor* (Gastropoda: Nudibranchia) in the SCI "fondali Noli - Bergeggi" (Ligurian Sea). *Marine Biodiversity Records*, 8, 1-4.

Bock, D.G., MacIsaac, H.J., Cristescu, M.E., 2012. Multilocus genetic analyses differentiate between widespread and spatially restricted cryptic species in a model ascidian. *Proceedings of the Royal Society*. B 279, 2377-2385.

Bouda, A., Bachari, N.E.I., Bahmed, L., Boubenia, R., 2016. Design of a risk assessment methodology for the introduction of invasive species from ship ballast waters: The case of Arzew port. *Management of Environmental Quality: An International Journal*, 27 (5), 474-490.

Bouda, A., Bachari, N.E.I., Nacef, L., Bensari, B., 2018. Risk Analysis of Invasive Species Introduction in the Port of Arzew, by Calculation of Biofouling Surface on Ships' Hulls. *Environmental Modeling and Assessment*, 23 (2), 185-192.

Calvet, L., 1902. Bryozoaires marins des côtes de corse. *Institut de zoologie de l'université de Montpelier*, 2 (12), 1-52.

Carlton, J.T., 2005. Setting ascidian invasions on the global stage. International Invasive Sea Squirt Conference. Woods Hole Oceanographic Institution, 21-22 April 2005, Woods Hole.

Carver, C.E., Mallet, A.L., Vercaemer, B., 2006. *Biological synopsis of the colonial tunicates, Botryllus schlosseri and Botrylloides violaceus*. Canadian Manuscript Report of Fisheries and Aquatic Sciences (CMRFAS), CMRFAS Technical report, No 2747, 42 p.

Cervera, J.L., Tamsouri, N., Moukrim, A., Villani, G., 2010. New records of two alien opisthobranch molluscs from the north-eastern Atlantic: *Polycera hedgpethi* and *Godiva quadricolor*. *Marine Biodiversity Records,* 3, 1-4.

Cohen, A., Carlton, J., 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and delta. United States Fish and Wildlife Service Washington D. C. (USFWSWDC) and The National Sea Grant College Program Connecticut Sea Grant (NSGCPCSG), CMRFASWDC and NSGCPCSG Technical report, No PB96-166525, 247 p.

Coll, M., Piroddi, C., Steenbeek, J., Kaschner, K., Lasram, *et al*., 2010. The biodiversity of the Mediterranean Sea: Estimates, patterns, and threats. *PLoS ONE*, 5 (8), e11842.

D'Hondt, J.L., Ben Ismail, D., 2008. Bryozoa from the Algerian coasts. Complementary data on Tunisian Bryozoa. *Bulletin de La Société Zoologique de France*, 133 (1–3), 55-71.

Edmunds, M., 1977. Larval development, oceanic currents, and origins of the opisthobranch fauna of Ghana. *Journal of Molluscan Studies* 43, 301-308.

Fehlauer-Ale, K.H., Mackie, J.A., Lim-Fong, G.E., Ale, E., Pie, M.R., *et al.,* 2014. Cryptic species in the cosmopolitan *Bugula neritina* complex (Bryozoa, Cheilostomata). *Zoologica Scripta*. 43 (2), 193-205.

Galil, B.S., 2009. Taking stock: inventory of alien species in the Mediterranean Sea. *Biological Invasions*, 11, 359-372.

Gautier, Y.V., 1955. Bryozoaires de Castiglione. *Bulletin des travaux de la Station d'Aquiculture et de Pêche de Castiglione*, 7, 227-273.

Gerovasileiou, V., Akel, E.H.Kh., Akyol, O., Alongi, G., Azevedo, F. *et al.,* 2017. New Mediterranean Biodiversity Records (July, 2017). *Mediterranean Marine Science*, 18, 355-384.

Glasby, T.M., Connell S.D., Holloway M.G., Hewitt C.L., 2007. Nonindigenous biota on artificial structures: could habitat creation facilitate biological invasions? *Marine Biology*, 151, 887-895,

Gollasch, S., 2002. The importance of ship hull fouling as a vector of species introductions into the North Sea. *Biofouling*, 18, 105-121.

Grimes, S., (2010). *Peuplements Benthiques Des Substrats Meubles De La Cote Algerienne*. PhD Thesis. Université d'Oran, Algeria, 360 pp.

Grimes, S., Benabdi, M., Babali, N., Refes, W., Boudjellal-Kaidi, N., *et al.,* 2018. Biodiversity changes along the Algerian coast (Southwestern Mediterranean basin) from 1834 to 2017. First assessment of introduced species, *Mediterranean Marine Science*, 19 (1), 156-179.

Hewitt, C.L., Campbell, M.L., 2001. The Australian distribution of the introduced Sphaeromatid Isopod, *Paracerceis sculpta*. *Crustaceana*, 74 (9), 925-936.

Hewitt, C.L., Martin, R.B., 2001. *Revised protocols for baseline port surveys for introduced marine species: survey design, sampling protocols and specimen handling*. Centre for Research on Introduced Marine Pests (CRIMP), CRIMP Technical report, No 22, 46 pp.

Katsanevakis, S., Wallentinus, I., Zenetos, A., Leppäkoski, E., Çinar, M.E. *et al*., 2014. Impacts of invasive alien marine species on ecosystem services and biodiversity: a pan-European review. *Aquatic Invasions*, 9 (4), 391-423.

Klautau, M., Monteiro, L., Borojevic, R., 2004. First occurrence of the genus *Paraleucilla* (Calcarea, Porifera) in the Atlantic Ocean: *P. magna sp. nov*. *Zootaxa*, 710, 1-8.

Lejeusne, C., Bock, D.G., Therriault, T.W., Macisaac, H.J., Cristescu, M.E., 2011. Comparative phylogeography of two colonial ascidians reveals contrasting invasion histories in North America. *Biological Invasions*, 13, 635-650.

Lopez-Legentil, S., Turon, X., Planes, S., 2006. Genetic structure of the star sea squirt, *Botryllus schlosseri,* introduced in southern European harbours. *Molecular Ecology*, 15, 3957-3967.

Marchini, A., Cardeccia, A., 2017. Alien amphipods in a sea of troubles: cryptogenic species, unresolved taxonomy and overlooked introductions. Marine Biology, 164:69.

Masunari, S., Sieg, J., 1980 Morphological and ecological notes on *Zeuxo coralensis* Sieg, 1980 from Brazil. *Studies on Neotropical Fauna and Environment*, 15 (1), 1-8.

Munguia, P., Shuster, S.M., 2013. Established populations of *Paracerceis sculpta* (Isopoda) in the Northern Gulf of Mexico. *Journal of Crustacean Biology*, 33 (1), 137-139.

Neves C., Rocha, R., Pitombo, F., Roper, J., 2007. Use of artificial substrata by introduced and cryptogenic marine species in Paranaguá Bay, southern Brazil. *Biofouling*, 23, 319-330.

Pierri, C., Longo, C., Giangrande, A., 2010. Variability of fouling communities in the Mar Piccolo of Taranto (Northern Ionian Sea, Mediterranean Sea). *Journal of the Marine Biological Association of the United Kingdom*, 90 (1), 159-167.

Ramadan, S.E., Kheirallah, A.M., Abdel-Salam, K.M., 2006. Marine fouling community in the Eastern harbour of Alexandria, Egypt compared with four decades of previous studies. *Mediterranean Marine Science*, 7 (2), 19-30.

Rebzani-Zahaf, C., 2003. *Les peuplement macrobenthiques des milieux portuaires de la côte algérienne : Alger, Bejaia et Skikda*. PhD Thesis. Université des Sciences et de la Technologie Houari Boumediene, Algeria, 244 pp.

Reem, E., Douek, J., Paz, G., Katzir, G., Rinkevich, B., 2017. Phylogenetics, biogeography and population genetics of the ascidian *Botryllus schlosseri* in the Mediterranean Sea and beyond. *Molecular Phylogenetics and Evolution*, 107, 221-231.

REMPEC, 2008. Report of the second meeting of the regional study group GLOBALLAST. The Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), REMPEC Technical report, No WG.31/8 40p.

Rezig, M., 1978. Sur la présence de *Paracerceis sculpta* (Crustacé, Isopode, Flabellifère) dans le Lac de Tunis. *Bulletin Office National Pêches Tunisie*, 2, 175-191.

Ryland, J.S., 1960. The British species of Bugula (Polyzoa). *Proceedings of the Zoological Society of London*, 134, 65-105.

Ryland, J.S., Bishop, J.D.D., Blauwe, H.D, Nagar, A. El, Minchin, *et al.,* 2011. Alien species of Bugula (Bryozoa) along the Atlantic coasts of Europe. *Aquatic Invasions,* 6 (1), 17-31.

Sánchez-Moyano, J.E., García-Gómez, J.C., 1998. The arthropod community, especially crustacea, as a bioindicator in Algeciras Bay (Southern Spain) based on a spatial distribution. *Journal of Coastal Research*, 14 (3), 1119-1133.

Sghaier, Y.R., Zakhama-sraieb, R., Charfi, F., 2019. An inventory of non-indigenous species (NIS) inside and outside three tourist marinas from the southern Mediterranean coast outside three tourist marinas from the southern. *Journal of the Black Sea / Mediterranean Environment*, 5 (1), 29-48.

Spagnolo, A., Auriemma, R., Bacci, T., Balković, I., Bertasi, *et al.,* 2019. Non-indigenous macrozoobenthic species on hard substrata of selected harbours in the Adriatic Sea. *Marine Pollution Bulletin*, 147, 150-158.

Streftaris, N., Zenetos, A., 2006. Alien marine species in the Mediterranean - the 100 'worst invasives' and their impact. *Mediterranean Marine Science*, 7, 87-118.

Sun, Y., Wong, E., Keppel, E., Williamson, J.E., Kupriyanova, E.K., 2017. A global invader or a complex of regionally distributed species? Clarifying the status of an invasive calcareous tubeworm *Hydroides dianthus* (Verrill, 1873) (Polychaeta: Serpulidae) using DNA barcoding. *Marine Biology*, 164:28.

Ulman, A., Ferrario, J., Occhpinti-Ambrogi, A., Arvanitidis, C., Bandi, A., *et al.,* 2017. A massive update of non-indigenous species records in Mediterranean marinas. PeerJ 5, e3954.

Willan, R.C., 1987. Phylogenetic systematics and zoogeography of Australian nudibranchs: 1. Presence of the aeolid *Godiva quadricolor* (Barnard) in Western Australia. *Journal of the Malacological Society of Australia*, 8, 7185.

WoRMS Editorial Board, 2020. World Register of Marine Species. Available from http://www.marinespecies.org at VLIZ. Accessed 2020-01-05.

Zakhama-Sraieb, R., Charfi-Cheikhrouha, F., 2010. First record of two lessepsian amphipods in Tunisia: *Elasmopus pectenicrus* and *Stenothoe gallensis*. *Journal of the Marine Biological Association of the United Kingdom*, 90 (7), 1291-1295.

Zenetos, A., Çinar, M. E., Crocetta, F., Golani, D., Rosso, A., *et al.,* 2017. Uncertainties and validation of alien species catalogues: The Mediterranean as an example. *Estuarine, Coastal and Shelf Science, 191, 171*–187.

Zenetos, A., Gofas, S., Morri, C., Rosso, A., Violanti, D., *et al.,* 2012. Alien species in the Mediterranean Sea by 2012. A contribution to the application of European Union's Marine strategy framework directive (MSFD). Part 2. Introduction trends and pathways. *Mediterranean Marine Science*, 13 (2), 328-352.

Zenetos, A., Gofas, S., Verlaque, M., Çinar, M.E., García Raso, J.E., *et al.,* 2010. Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union's Marine strategy framework directive (MSFD). Part I. Spatial distribution. *Mediterranean Marine Science,* 11 (2), 381-493.

Zibrowius, H., 1973. Remarques sur trois espèces de Serpulidae acclimatées en Méditerranée : *Hydroides dianthus* (Verrill, 1873), *Hydroides dirampha* Mörch, 1863, et *Hydroides elegans* (Haswell, 1883). Rapport de la *Commission internationale pour l'exploration scientifique de la Méditerranée*, 21 (9), 683-686.

Zibrowius, H., 1991. Ongoing modification of the Mediterranean marine fauna and flora by the establishment of exotic species. *Mésogée*, 51, 83-07.

Supplementary data

The following supplementary information is available on line for the article:

Table S1. Collection dates, coordinates, substratum, number of specimens collected and abundance estimation by *in situ* observation for all NIS and cryptogenic species reported in this study. NSC = Number of Specimens Collected, AEISO = Abundance Estimation by *in Situ* Observation.