

RESEARCH ARTICLE

An inventory of non-indigenous species (NIS) inside and outside three tourist marinas from the southern Mediterranean coast

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Abstract

In December 2013, three marinas in the southern Mediterranean coasts, El Kantaoui and Cap Monastir in the central east coast of Tunisia and Marina El Alamein in the central coast of Egypt, were surveyed for the presence of non-indigenous species (NIS). In order to maximize the number of collected species and to sample the full range of biotic assemblages and microhabitats inside and outside the marinas, diverse survey methods were employed. These include rapid assessment surveys of epibiota on artificial structures in harbors, with standardized one-hour transects used for snorkeling and diving to observe infra-littoral species and traps for catching small crabs and shrimps. Other data were obtained from the catch composition of coastal fishing boats operating in the area. A total of 26 NIS originating from Indo-Pacific Ocean/Red Sea were identified as 6 macrophyte, 11 invertebrate and 9 fish species. The results highlight the role of marinas in the introduction of NIS into the Mediterranean. Further and regular surveys in risk areas are recommended to provide an effective early warning system for NIS.

Keywords: Biofouling, non-indigenous species, marina, Tunisia, Egypt, Mediterranean Sea

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Introduction

Non-indigenous species (NIS), also known as exotic, alien, introduced, or non-native species, are species of fauna or flora which are introduced outside their

natural past or present distribution range by human agency, either directly or indirectly (European Environment Agency 2012). The invasion of NIS in the Mediterranean Sea has been recorded for many years, fostered by the opening of the Suez Canal, fouling and ballast transportation, aquaculture, aquarium trade, and global climate change (Zenetos *et al.* 2012). Some NIS have clear negative impacts on biodiversity, public health, and cause economic and cultural issues in the affected areas (Katsanevakis *et al.* 2014).

All over the world, NIS vectors are highly associated with economic activities such as trade and tourism. During the last decades, records of NIS in ports around the world (Carlton 1989; Ruiz *et al.* 2000) and particularly the Mediterranean Sea have increased (Hoffman *et al.* 2011; Ferrario *et al.* 2017), often seriously endangering natural habitats (Hoffman 2013). The proliferation of marinas for recreational vessels over recent decades is a worldwide phenomenon (Minchin *et al.* 2006). Moreover, development and expanded tourism in coastal regions have increased the number of man-made artificial structures (commercial, recreational, residential) such as ports and marinas. Furthermore, ports, marinas and recreational vessels have become increasingly implicated in the spread of marine NIS making ports and marinas ideal gateways for introduced species (Clarke Murray *et al.* 2012) and thereby contribute to their successful establishment (Otero *et al.* 2013).

In the southern Mediterranean countries, despite the efforts displayed in the last decade regarding the monitoring and reporting of NIS distributions (Bazairi *et al.* 2013; Dorgham *et al.* 2013; Halim and Rizkalla 2011; Ounifi-Ben Amor *et al.* 2016; Sghaier *et al.* 2016), the knowledge gap between the Mediterranean's northern and southern coasts is still huge.

During the 19th Meeting of the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, the "Integrated Monitoring and Assessment Program of the Mediterranean Sea and Coast and Related Assessment Criteria" (IMAP) was adopted. During the initial phase of IMAP (2016-2019), the Mediterranean countries must design and carry out their national integrated monitoring programs in order to cover the IMAP objectives and common indicators (UN Environment/MAP 2017).

The common indicator 6 of the IMAP is related to NIS "trends in abundance, temporal occurrence, and spatial distribution of NIS, particularly invasive NIS, notably in risk areas (in relation to the main vectors and pathways of spreading of such species...)" (UN Environment/MAP 2017). Consequently, the aim of this study is therefore to detect NIS inside and around three southern Mediterranean marinas using suitable and practicable tools (Rapid Assessment Surveys) and to provide baseline data for further monitoring studies. The role of small vessels and fishing boats in spreading NIS is also discussed.

Materials and Methods

Study area

Our research was conducted in three Mediterranean marinas from the south Mediterranean (El Kantaoui and Cap Monastir in Tunisia and Marina El Alamein in Egypt) during December 2013 (Figure 1). The sampling was carried out during winter in order to detect established NIS in these marinas.

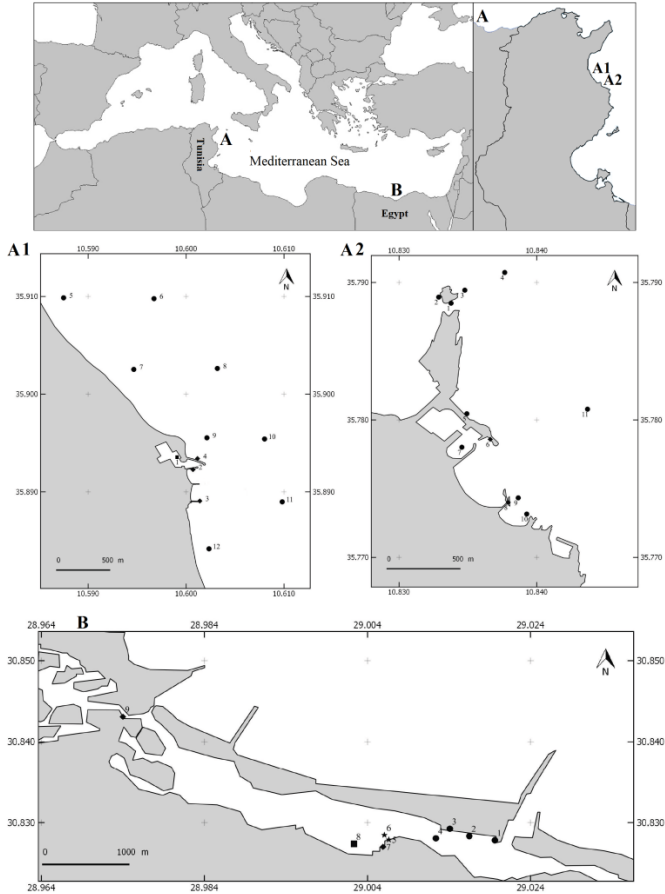


Figure 1. Map of sampling stations in the three marinas
A: Tunisia, **A1:** Marina port El Kantaoui, **A2:** Marina Cap Monastir, **B:** Marina El Alamein, Egypt.

Used method: Scuba ●, Trap/fisher ★, by hand ■, Snorkeling ◆

Table 1. Sampling stations characteristics and sampling method used at the three marinas

Marina Port El Kantaoui, Tunisia					
Station	Latitude	Longitude	Depth(m)	Bottom	Sampling method
1	35.893624°	10.599428°	1-3	Rocky, sandy	Snorkel/fisher
2	35.892311°	10.600716°	1-3	Rocky, sandy	Snorkel
3	35.889102°	10.601412°	1-3	Rocky, sandy	Snorkel
4	35.893435°	10.601175°	1-3	Sandy and dead matte of <i>Posidonia oceanica</i>	Snorkel
5	35.909895°	10.587495°	2-6	Sandy	Scuba diving
6	35.909809°	10.596733°	8-10	Sandy	Scuba diving
7	35.902567°	10.594670°	2-6	Sandy and dead matte of <i>Posidonia oceanica</i>	Scuba diving
8	35.902666°	10.603204°	8-10	Sandy	Scuba diving
9	35.895566°	10.602134°	4-6	Sandy and dead matte of <i>Posidonia oceanica</i>	Scuba diving
10	35.895447°	10.608030°	8-10	Sandy	Scuba diving
11	35.889014°	10.609834°	8-10	Sandy	Scuba diving
12	35.884205°	10.602350°	2-5	Sandy	Scuba diving
Marina Cap Monastir, Tunisia					
Station	Latitude	Longitude	Depth(m)	Bottom	Sampling method
1	35.788529°	10.833782°	0-5	Rocky	Snorkel
2	35.788970°	10.832887°	0-5	Rocky	Snorkel
3	35.789475°	10.834783°	5-15	Rocky, sandy	Scuba diving
4	35.790762°	10.837686°	23-25	Sandy, rocky	Scuba diving
5	35.780482°	10.834932°	5	Rocky	Scuba diving
6	35.778619°	10.836632°	2-5	Sandy, rocky	Snorkel diving
7	35.778044°	10.834568°	1-5	Muddy, sandy	Scuba diving /fisher
8	35.774031°	10.837946°	1-5	Rocky	Snorkel
9	35.774359°	10.838667°	4-6	Rocky, sandy	Scuba diving
10	35.773184°	10.839285°	4-6	Rocky, sandy	Scuba diving
11	35.780814°	10.843702°	29	Sandy	Scuba diving
Marina El Alamein, Egypt					
Station	Latitude	Longitude	Depth(m)	Bottom	Sampling method
1	30.827833°	29.020000°	8	Sandy, muddy	Scuba diving
2	30.828350°	29.016850°	8	Sandy, muddy	Scuba diving
3	30.829250°	29.014450°	8	Rocky	Scuba diving
4	30.828067°	29.012733°	8	Rocky, sandy	Scuba diving
5	30.827900°	29.006933°	3	Rocky	Trap/fisher
6	30.828467°	29.006383°	4	Rocky	Trap
7	30.827017°	29.006217°	1	Rocky	Snorkel
8	30.827383°	29.002633°	0.2	Rocky	Hand
9	30.843100°	28.974150°	1	Rocky	Snorkel

Tunisia, with more than 1,400 km of coastline, is in a key location and a crossroads between the different Mediterranean basins. The Tuniso-Sicilian Strait is the passageway separating the basins into north and south and east to west, and is crucial in the analysis of the spread of NIS in the Mediterranean Sea.

Marina Cap Monastir, located in the southern part of the Gulf of Hammamet (35.778044°N, 10.834568°E) was built in 1995. The marina is divided into two basins; the first one mainly accommodates small fishing boats, while the second basin is planned to support 400 international recreational boats in a 900 m quay. The water covers 4 hectares with a depth varying between 2 and 15 m and the marina is connected to the sea via a 35m-long access channel (Maurice and Lockyear 1983). In this study, eleven stations were selected around Marina Cap Monastir (Figure 1, Table 1) and surveyed at a depth of between 1 and 10 m for the presence of marine NIS.

Marina Port El Kantaoui is located in the south of the Gulf of Hammamet, about 8 km northwest of the port of Sousse (35.893703°N, 10.598558°E). The construction of the marina began in 1971 and finished in 1979. This marina is one of the units that make up the tourist resort of El Kantaoui with 340 berths for luxury yachts along a 1,425 m quay (Maurice and Lockyear 1983). The water covers 4.2 hectares with a depth varying between 2 and 4 m. An access channel, 100 m long and dredged to 4 m deep, connects the marina and the sea. Ten fishing boats are kept near the channel in the marina (Zakhama-Sraieb *et al.* 2016). Twelve stations were selected inside and outside Marina Port El Kantaoui (Figure 1, Table 1) and surveyed for the presence of marine NIS.

The Mediterranean coast of Egypt extends along 1,050 km from Rafah in the east, on the Sinai Peninsula, to Sallum in the west, on the Egyptian-Libyan border. It is one of the longest Mediterranean shores in North Africa. Marina El Alamein (30.833829°N, 28.984759°E) is located in the El Alamein area, 100 km west of Alexandria and 300 km from Cairo. Marina El Alamein is situated in a lagoon which is about 9.5 km long with a maximum width of 0.65 km and an average depth of 3.5 m. Nine stations were randomly selected inside Marina El Alamein and the lagoon (Figure 1, Table 1) and surveyed for the presence of any benthic NIS at a depth between 0 and 8 m.

Data and survey methods

The survey contributors attempted to sample the full range of biotic assemblages represented by the available substrates and microhabitats inside and outside the marinas in order to collect as many NIS as possible.

Inside the marinas: Rapid assessment surveys (Pederson *et al.* 2003) were undertaken by a team of four surveyors. It took 1-2 hours at each marina. Float fouling (organisms growing on the sides and undersides of floating docks and

associated bumpers, tires, ropes, *etc.*) and organisms fouling on fixed subtidal and intertidal structures (pilings, bridge supports, *etc.*) were sampled using scrapers and other hand-held tools.

Outside the marinas: Benthic epifauna and flora taxa were collected from a depth of 0-29 m through snorkeling and scuba diving on several substrata (hard, soft bottom and meadows). For snorkeling and diving, standardized one-hour transects were used.

In addition to these surveys, and in order to have more information regarding NIS, other data were obtained from catch composition of artisanal fishing boats operating near those marinas and fish traps were used to catch small crabs and shrimps in Marina El Alamein.

All biofouling samples and observed species were collected and preserved in alcohol until their identification in the laboratory. The abundance of the species was categorized as: low (1-5 individuals or algal/seagrass surface area of up to 20 cm²), medium (5-100 individuals or algal/seagrass surface area of 20-100 cm²) or high (>100 individuals or algal/seagrass surface area of over 100 cm²) at each marina. The material sampled was deposited at the Laboratory of Diversity, Management and Conservation of Biological Systems, Faculty of Sciences of Tunis, University Tunis El Manar.

Nomenclature adopted in this paper follows the World Register of Marine Species (WoRMS www.marinespecies.org) and contributing databases (AlgaeBase www.algaebase.org, CLEMAM www.mnhn.fr/base/malaco, FishBase www.fishbase.org, MAMIAS www.mamias.org).

Results

As a result of the investigations carried out in three southern Mediterranean marinas, a total of 27 NIS (Table 2, Figure 2) were identified (6 macrophyte, 12 invertebrate and 9 fish species), of which 24 have an Indo-Pacific/Red Sea origin. Five species of NIS algae were found, with three species of Chlorophyta and two Rhodophyta. No macrophyte NIS were found in Marina El Alamein during our survey. The keyhole limpet *Diodora ruppellii* (G. B. Sowerby I, 1835) and the ascidian *Symplegma brakenhielmi* (Michaelsen, 1904) were recorded for the first time in Egypt. The sponge *Paraleucilla magna* (Klautau, Monteiro & Borojevic, 2004) and the ascidian *S. brakenhielmi* were new records for Tunisia.



Figure 2. NIS found in this study

- A:** *Caulerpa cylindracea*, **B:** *Caulerpa taxifolia*, **C:** *Codium fragile* subsp. *fragile*,
D: *Asparagopsis armata* **E:** *Asparagopsis taxiformis*, **F:** *Halophila stipulacea*,
G: *Paraleucilla magna*, **H:** *Erugosquilla massavensis*, **I:** *Charybdis* (*Charybdis*) *hellerii*,
J: *Portunus* (*Portunus*) *pelagicus*, **K:** *Percnon gibbesi*, **L:** *Cerithium scabridum*

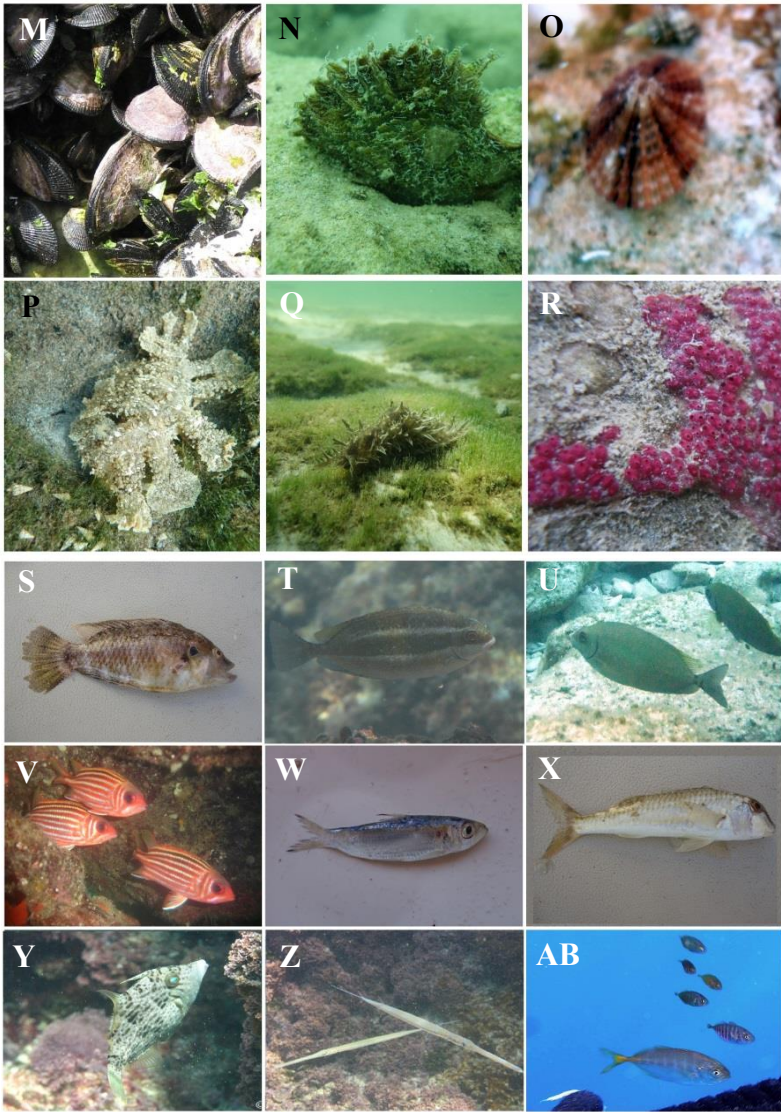


Figure 2. Continued.

M: *Brachidontes pharaonis*, **N:** *Pinctada imbricata radiata*,
O: *Diodora ruppellii*, **P:** *Melibe viridis*, **Q:** *Bursatella leachii*, **R:** *Symplegma brakenhielmi*, **S:** *Pteragogus pelycus*, **T:** *Siganus luridus*, **U:** *Siganus rivulatus*,
V: *Sargocentron rubrum*, **W:** *Herklotsichthys punctatus*, **X:** *Upeneus moluccensis*,
Y: *Stephanolepis diaspros*, **Z:** *Fistularia commersonii*, **AB:** *Alepes djedaba*.
 (Photos M, U, Y and Z © Ghazi Bitar)

First record of Non-Indigenous Species

***Diodora ruppellii* (G. B. Sowerby I, 1835)**

Three specimens of *Diodora ruppellii* were collected in the underpart of rocks at a depth of 1 m by snorkeling in station 7 of the Marina El Alamein lagoon (Figure 2O). *D. ruppellii* had a whitish shell with radial sectors bearing dark blotches, with a white inside and external patterns showing through. The shell lengths were between 7 mm and 10 mm. *D. ruppellii* is an omnivore, feeds on marine vegetation in sand ground and on sponges lining the underpart of rocks. *D. ruppellii* was first recorded in Palestine (Haas 1948) and later in the southeast coast of Turkey in the Gulf of Iskenderun to Alanya (Engl 1995).

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

Samples of the sponge *Paraleucilla magna* (Figure 2G) were collected by hand in Marina Cap Monastir from floating docks, ropes and boats fouling in very shallow areas (depth > 1m). This sponge has been relatively recently seen and described in the Brazilian Atlantic Coast where it is one of the most abundant calcareous sponges (Klautau *et al.* 2004). In the Mediterranean Sea, *P. magna* is the only sponge considered to be a NIS, reported in the southern Italian coasts (Longo *et al.* 2007), in Malta (Zammit *et al.* 2009), along the northwestern coast of the West Basin, in the northeast of the Iberian Peninsula (Guardiola *et al.* 2012), in Croatia (Cvitković *et al.* 2013), in Boka Kotorska Bay, in Montenegro (Mačić and Petović 2016), in the Sea of Marmara (Topaloğlu *et al.* 2016) and in the Aegean Greek waters (Gerovasileiou *et al.* 2017).

***Symplegma brakenhielmi* (Michaelsen, 1904)**

The reddish variety of the colonial ascidian *Symplegma brakenhielmi* was abundant in the three marinas. *S. brakenhielmi* (Figure 2R) was found to be an epiphyte of *Halophila stipulacea* and *Cymodocea nodosa* in Marina Cap Monastir, and fixed to natural rock or artificial substrate (floating docks, ropes, boats fouling) in the three marinas. In Marina El Alamein and El Kantaoui, the colonies were found at shallow depths (1m). However, *S. brakenhielmi* was found at depth ranging from 1 to 5 m in Marina Cap Monastir. The diameter of the colonies varied between 5 and 7 cm. The zooids were embedded in a common tunic, with the two very short siphons opening for each zooid creating a beehive appearance. *S. brakenhielmi* was collected for the first time in Haifa Bay in 1975 and misidentified as *S. viride* (Shenkar and Loya 2009). Since, *S. brakenhielmi* has spread to the Lebanese coast (Bitar and Kouli-Bitar 2001), to the south of Turkey (Çinar *et al.* 2006) and to Marina Villa Igiea, Palermo (Ulman *et al.* 2017). This species has spread worldwide to warmer seas, especially in harbors, where it grows on man-made structures (Lambert and Lambert 1998).

Table 2. Marine NIS recorded in the three marinas from the South Mediterranean coast. First records in the marina are marked by *.
 Origin- IP: Indo-Pacific, NWP: North-West Pacific, SWP: South-West Pacific, RS: Red Sea, IO: Indian Ocean, SWA: South-West Atlantic,
 WA: West Atlantic, T: tropical, IWP: Indo-West Pacific, C: Circumtropical.

Grey square: presence of NIS in the site; black square : NIS caught by fishing boats

	Marina Port El Kantaoui (Tunisia)												Marina Cap Monastir (Tunisia)												Marina El Alamein (Egypt)											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9				
NIS																																				
Chlorophyta																																				
<i>Caulerpa cylindracea</i> Sonder, 1845																																				
<i>Caulerpa taxifolia</i> (M. Vahl) C. Agardh, 1817																																				
<i>Codium fragile</i> subsp. <i>fragile</i> (Suringar) Hariot, 1889																																				
Rhodophyta																																				
<i>Asparagopsis armata</i> Harvey, 1855																																				
<i>Asparagopsis taxiformis</i> (Delile) Trevisan de Saint-Léon, 1845																																				
Magnoliophyta																																				
<i>Halophila stipulacea</i> (Forsskål) Ascherson, 1867																																				
Porifera																																				
<i>Paraleucilla magna</i> * Klautau, Monteiro and Borojevic, 2004																																				
Crustacea																																				
<i>Erugosquilla massavensis</i> (Kossmann, 1880)																																				
<i>Charybdis (Charybdis) hellerii</i> (A. Milne-Edwards, 1867)																																				
<i>Portunus (Portunus) pelagicus</i> (Linnaeus, 1758)																																				
<i>Percnon gibbesi</i> (H. Milne Edwards, 1853)																																				
Mollusca																																				
<i>Cerithium scabridum</i> Philippi, 1848																																				
<i>Brachidontes pharaonis</i> (P. Fischer, 1870)																																				
<i>Pinctada imbricata radiata</i> (Leach, 1814)																																				
<i>Diodora ruppellii</i> * (G. B. Sowerby I, 1835)																																				
<i>Melibe viridis</i> (Kelaart, 1858)																																				
<i>Bursatella leachii</i> De Blainville, 1817																																				

New knowledge on NIS distribution

***Charybdis (Charybdis) hellerii* (A. Milne-Edwards, 1867)**

A male specimen of the Indo-Pacific portunid crab *C. hellerii* with a carapace length of 4.5 cm was collected by scuba diving in a sandy area with stones at a depth of 8 m in the Marina El Alamein lagoon. *C. hellerii* (Figure 2I) differs from the other exotic *Charybdis* spp. in having a smooth lower surface of chela and the carpus of the fifth leg bearing the posterior spine. According to Galil and Zenetos (2002), *C. hellerii* was first sighted in the Mediterranean Sea off the Israeli coasts in 1924-1925 (Steinitz 1929) and has since been seen off the coast of Egypt, Lebanon, Syria, Turkey and Cyprus (Galil 1993; Zibrowius pers. comm.). *C. hellerii* was collected for the first time in Egypt by Balls (1936) as *Charybdis (Goniosoma) merguiensis*.

***Melibe viridis* (Kelaart, 1858)**

More than 20 specimens of *M. viridis* were recorded by scuba diving drifting, swimming and crawling around in the Marina Cap Monastir in mixed *Halophila stipulacea* and *Cymodocea nodosa* meadows in a sandy muddy bottom between 1 and 5 m deep. *M. viridis* (Figure 2P) measured between 40 and 164 mm in length. The first Mediterranean record of this species (as *Melibe fimbriata*) was in Italy in 1970 (Moosleitner 1986). It has also been recorded in Greece and Tunisia (Cattaneo-Vietti *et al.* 1990; Antit *et al.* 2011), Croatia (Despalatovic *et al.* 2002), Turkey (Yokes and Rudman 2004), Montenegro (Jancic 2004) and Cyprus (Sanchez Villarejo 2007). This record in Marina Cap Monastir represents the new southern limit for its distribution in Tunisia and in the southern Mediterranean.

***Halophila stipulacea* (Forsskål) Ascherson, 1867**

Numerous living *Halophila stipulacea* fragments were observed among seaweed along the shoreline near the Cap Monastir Marina. The presence of *H. stipulacea* meadows was confirmed within the Cap Monastir Marina in May 2011 (Sghaier *et al.* 2011) where it grew on a mixed sand/stone bottom at a depth of 0.5-4 m. For El Kantaoui, small patches of *H. stipulacea* (Figure 2F) were observed in the marina close to fishing boats near the access channel. The occurrence of this species in Marina El Kantaoui makes it the new northern front edge of the species' distribution along the southern coast of Tunisia and the Mediterranean.

Abundance of NIS

The abundance of the NIS in the three marinas is shown in Table 2. Marina El Alamein has nine NIS with high abundance (*Erugosquilla massavensis*, *Portunus (Portunus) pelagicus*, *Cerithium scabridum*, *Brachidontes pharaonis*, *Pinctada imbricata radiata*, *Symplegma brakenhielmi*, *Siganus luridus*, *S. rivulatus*, *Herklotsichthys punctatus*). In Marina Cap Monastir there are seven

NIS with high abundance (*Caulerpa cylindracea*, *C. taxifolia*, *Asparagopsis taxiformis*, *Halophila stipulacea*, *Percnon gibbesi*, *Cerithium scabridum*, *Symplegma brakenhielmi*) and five in El Kantaoui (*Caulerpa cylindracea*, *Caulerpa taxifolia*, *Percnon gibbesi*, *Cerithium scabridum*, *Symplegma brakenhielmi*).

Discussion

In three marinas we studied in the southern Mediterranean, 27 NIS were recorded. These include *Diodora ruppellii*, *Symplegma brakenhielmi* and *Paraleucilla magna* which were recorded for the first time in the southern Mediterranean coast. The NIS recorded were classified as established and were widely distributed in their respective marinas. The recently arrived species in Tunisia, *S. brakenhielmi* and *P. magna*, may soon become established because they were reported to be abundant in the areas where they are present.

Despite the efforts made by experts in the last decade in Tunisia (Antit *et al.* 2011; Sghaier *et al.* 2016; Ounifi-Ben Amor *et al.* 2016) and Egypt (Halim and Rizkalla 2011; Dorgham *et al.* 2013), the number of NIS in the Egyptian Mediterranean waters and along the Tunisian coast probably remains underestimated due to the lack of experts and weak monitoring.

According to Ounifi-Ben Amor *et al.* (2016) and Sghaier *et al.* (2016), a total of 163 NIS were reported until March 2015 in Tunisian waters, among which there are four species of Ascidiacea (*Cystodytes philippinensis* Herdman, 1886, *Microcosmus exasperatus* Heller, 1878, *Trididemnum savignii* (Herdman, 1886) and *Microcosmus squamiger* Michaelsen, 1927). With the new records presented here for *P. magna* and *S. brakenhielmi*, the total number of NIS fauna increases to 165. For Egypt, according to the Marine Mediterranean Invasive Alien Species (MAMIAS) database (UNEP-MAP-RAC/SPA, 2015), 235 NIS had been reported by 2010. With the new records of *S. brakenhielmi* and *D. ruppellii*, the total number of NIS reported in Egypt increases to 237.

In the Marina El Alamein lagoon, the rocks were completely barren which is typically caused by the grazing of abundant sea urchins. However, no sea urchins were observed during our sampling in the lagoon. The high abundance of two herbivorous fish species belonging to Family Siganidae, *Siganus luridus* and *S. rivulatus*, are known to cause a dramatic reduction in biodiversity, biomass and algal growth (Sala *et al.* 2011). Furthermore, the sampling time, performed in December which is a period of low algal production, could also explain the absence of NIS macrophyte in Marina El Alamein.

The biodiversity in the Mediterranean Sea is one of Egypt's major natural resources. However, the biological diversity of the Egyptian Mediterranean waters is deeply threatened by the high number of marine NIS (238 NIS

recorded). In fact, the NIS often represent a component of abrupt change which can cause serious economic and ecological implications (Grosholz 2002; Molnar *et al.* 2008; Katsanevakis *et al.* 2014).

This research performed along the Tunisian coasts revealed that El Kantaoui port and Marina Cap Monastir displayed a high number of recorded NIS. This confirms that the hotspots for NIS marine biota in the Mediterranean Sea are coastal lagoons and harbors, which is justified by the favorable conditions for the establishment of new species. In fact, the natural and anthropogenic disturbances that characterize such environments produce a depauperate low-competition biota that can easily be occupied by opportunistic species, including invaders brought by shipping and/or aquaculture (Occhipinti-Ambrogi and Savini 2003; Occhipinti-Ambrogi *et al.* 2011). For this reason, coastal lagoons and harbors have witnessed spectacular examples of biological invasions, such as those in San Francisco Bay in the United States (Cohen and Carlton 1998), the Thau Lagoon in France (Verlaque 2001), the Venice Lagoon (Occhipinti-Ambrogi *et al.* 2011), Haifa Bay (Hoffman *et al.* 2011) and the port of Iskenderun (Nunes *et al.* 2014). Furthermore, in a recent marine NIS assessment carried out in 2014 in the eastern Mediterranean on the island of Rhodes in Greece, a total of 33 NIS and cryptogenic species were reported and the number of NIS varied from 1 to 15 in the harbors.

In Tunisia, Monastir is the main introduction hotspot and this is likely due to many major vectors of transport located in the area such as a commercial port, a recreational marina and fish farms which combined facilitate the introduction and secondary dispersal of non-native organisms. Furthermore, the ecosystem of Monastir Bay is deeply affected by various anthropogenic activities which sometimes make environmental conditions less tolerable for some native species (Rilov and Crooks 2009).

The same properties that make marinas and ports safe sites for boats encourage the settlement and establishment of NIS. Moreover, ports and marinas are some of the most invaded marine areas in the world (Lambert and Lambert 1998) because they provide a suitable habitat for NIS, accelerating their spreading process (López-Legentil *et al.* 2015).

Monitoring the abundance and distribution patterns of NIS, particularly those that are invasive in nature, will help us detect problems early on, understand the relative risk of invasions by different species, identify the potential patterns of invasion and see how to elaborate management strategies to reduce further risks.

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