Mediterranean Marine Science

Vol 19, No 1 (2018)

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doi: 10.12681/mms.13824

Review Article

Mediterranean Marine Science
Indexed in WoS (Web of Science, ISI Thomson) and SCOPUS
The journal is available online at http://www.medit-mar-sc.net
DOI: http://dx.doi.org/10.12681/mms.13824

Biodiversity changes along the Algerian coast (Southwestern Mediterranean basin) from 1834 to 2017. First assessment of introduced species

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Handling Editor: Argyro Zenetos

Received: 9 May 2017; Accepted: 3 April 2108; Published on line: 23 May 2018

Abstract

The "Introduced" species of the Algerian coast remain the most undocumented issue in the Mediterranean Sea. Only few studies have been dedicated to Introduced species due to the lack of taxonomists. In-depth research on introduced species along the Algerian coast should provide new data that could explain the spreading mechanisms in the southwestern part of the Mediterranean basin, particularly near the Alboran Sea. Introduced species and other related research, the outcome of which is expected in the next few years, is in progress in the southwestern Mediterranean basin. The aim of this work is to provide an inventory of available data pertaining to marine species "introduced" in Algerian waters, whether these species were introduced intentionally or accidentally. The large number of introduced species records covers the period from 1834 to December 2017. Seventy "Introduced" species have been recorded along the Algerian coast, composed of true aliens (55.7%), range expanding species (25.7 %), cryptogenic species (15.7%) and vagrant species (2.9%), with a clear dominance of fish (38.57%) and macroalgae (30%). Approximately 348 introduction events have been reported; 64.9 % of them belong to macroalgae and one sighting out of two is made in the central region. The distribution and the status of introduced species in Algeria were evaluated. In total, 20% of the Introduced species can be considered as established along the Algerian coast, in particular the macrophyta, *Codium fragile* and *Ulva lactuca* as well as the cryptogenic species, *Oculina patagonica,* while *Asparagopsis armata, A. taxiformis and Caulerpa cylindracea* are considered as invasive.

Keywords: Non Indigenous Species, West Mediterranean basin, Algeria.

Introduction

Introduction of alien species to new ecosystems is considered a major threat to ecosystem biodiversity, structure and functioning (Katsanevakis *et al.*, 2014). Furthermore, it has been demonstrated that biological invasions in aquatic habitats may also impact ecosystem services and seriously affect local economies (Streftaris & Zenetos, 2006). Three main routes are frequently proposed to explain the arrival of these exotic elements in the Mediterranean; the most common is the influx from the Red Sea through the Suez Canal, followed by shipping, on ship hulls or in ballast water, and to a lesser extent by mariculture (Gofas & Zenetos, 2003). The Mediterranean Sea is considered a hotspot of biological invasions, due to climate change and its connection to the Red Sea via the Suez Canal. Indeed, the opening of the Suez Canal in 1869, with its heavy maritime traffic, has created a corridor between two distinct biogeographical provinces, the so-called "Lessepsian migration" of Indo-Pacific species into the Mediterranean (Por, 1978). Another anthropogenic factor, which is increasing in importance, are intentional releases of aquaria kept species that contribute significantly to the introduction of alien species in the Mediterranean as well as worldwide (Zenetos *et al.*, 2012; Katsanevakis *et al.*, 2014; Nunes *et al.*, 2014; Zenetos *et al.,* 2016).

During the last decade, scientific research has enriched our knowledge about biological invasions in many areas of the Mediterranean Sea. Research topics have dealt with various issues related to marine bioinvasions, such as cli-

mate change impacts, interaction with native species, impact on biodiversity structures, impact on ecosystem services (Katsanevakis et *al.*, 2014), gateways for invasions (Nunes *et al.,* 2014), evolution, range expansions and genetic identifications (Dewarumez *et al.,* 2011; Katsanevakis *et al.*, 2014; Zenetos *et al.*, 2017). In parallel to the introduction of alien species, many species continue to expand their geographic range by entering the Mediterranean via the Strait of Gibraltar unaided. Finally, there is a number of newly reported species in the Mediterranean whose origin cannot be traced, the so-called cryptogenic species. Approximately one thousand alien and cryptogenic species have been recorded in Mediterranean waters with an accelerated rate of discovery and predominance of benthos and fish species (Zenetos *et al.*, 2012). However, this rate seems to be decreasing since 2010 (Zenetos, 2017, Zenetos *et al.*, 2017).

Many Mediterranean countries still lack inventories of Non Indigenous Species (NIS). The understanding of integrated and cumulative impacts of bio-invasions on the structure and functioning of ecosystems requires a substantial research effort, in particular from countries with major gaps such as quantification and mapping of impacts in combination with human pressures and natural processes that facilitate invasions, as well as the operational mechanisms of bio-invasions.

The Algerian coast is not immune to these invasions and many tropical and Indopacific species have been recorded over the last years (Seridi, 2007; Sartoretto *et al.*, 2008; Kara & Oudjane, 2009; Bachir Bouiadjra *et al.*, 2010; Lamouti & Bachari, 2011; Kara *et al.*, 2012; Ould Ahmed *et al.*, 2013; Refes & Semahi, 2014; Grimes *et al.*, 2016). Regarding the length and the importance of the Algerian coast in sub-regional and regional processes, significantly more interest should be focused on NIS and in particular invasive species and their potential effects on marine and coastal biodiversity, especially in key ecosystems such as *Posidonia oceanica* and coralligenous beds. This assessment is conducted in order to take "*appropriate measures to regulate the intentional or accidental introduction of non-indigenous or genetically modified species into the wild and prohibit those that may have harmful impacts on the ecosystems, habitats or species*", as required by the Barcelona Convention through its Protocol concerning specially protected areas and biological diversity (UNEP-MAP RAC/SPA, 2005), which were supported by Decision IG.22/12 related to "Species Introductions and Invasive Species" (UNEP/DEPI)/MED WG.421/26).

This work aims to compile a checklist of introduced marine species reported from 1834 to 2017 in Algeria.

Material and Methods

General characteristics of the Algerian coastal zone

The Algerian coast extends over 1622 km of the southwestern Mediterranean coastline, from the Moroccan to the Tunisian borders. The Algerian coastline is characterised by narrow shelf with extended rocky bottom and its western part is under the Alboran Sea and influenced by Atlantic currents (Millot, 1999). This coastline presents a variety of habitats, from the dominant rocky shores, sometimes with high cliffs, to sandy beaches and dunes in most of the bays (Grimes *et al.*, 2010), while the continental shelf extends to other Mediterranean areas, such as the Gulf of Lion, the north and central Adriatic Sea and the Aegean Sea (Coll *et al.*, 2010).

The circulation of watermasses along the Algerian coast is characterized by intense mesoscale dynamics (Millot *et al.*, 1997). In the western Mediterranean, the flow of Atlantic Water exhibits some branching at 18° E after crossing the Alboran Sea (Millot, 1987; Brankart & Brasseur, 1998). The seasonal anticyclonic character of this branching in the Algerian basin has also been identified by Roussenov *et al.* (1995) and Zavatarelli & Mellor (1995). The Algerian basin, within the western Mediterranean, has a maximum depth of around 2500m and is connected with the Balearic basin by a series of sills (Moranta *et al.*, 1998).

Data collection

The present compilation of introduced species along the Algerian coast is based on all available data from various sources, such as scientific and grey literature, including technical reports, PhD and MSc theses, aliens and biodiversity databases in addition to websites (e.g. MAMIAS database (UNEP-MAP RAC/SPA, 2017) (http://www.mamias.org), Fishbase (http://www.fishbase.org), Global Invasive Species Database (GIDB), CIESM atlases (http://www.ciesm.org/online/atlas/index.htm), Global Biodiversity Information Facility (GBIF; http://www.gbif.org), the Global Invasive Species Information Network (GISIN; http://www.gisin.org), the Mediterranean Marine Invasive Species information system (MedMIS, managed by IUCN; http://www.iucn-medmis.org), congresses as well as unpublished observations. The year of first sighting is also reported for each species and a list of species introduced to Algeria is presented. The Algerian inventory of marine alien species is presented for the following groups: Macrophyta, Cnidaria, Mollusca (Bivalvia, Gastropoda), Crustacea (Decapoda), Polychaeta, Bryozoa, Vertebrata (Chondrichthyes, Osteichthyes) with new data presented from 25 geographic assessment areas. These 25 areas cover 69 sites where new records have been reported since 1834 (Fig. 1, Table 1). In case of imprecise geographical coordinates for the sightings, the coordinates of the center of the area or sighting locality have been considered. These coordinates are included in Table 1 in order to facilitate the approximate location of the detection area.

Nomenclature and species classification

The species are classified according to the terminology proposed by Zenetos *et al*. (2010) and taking into consid-

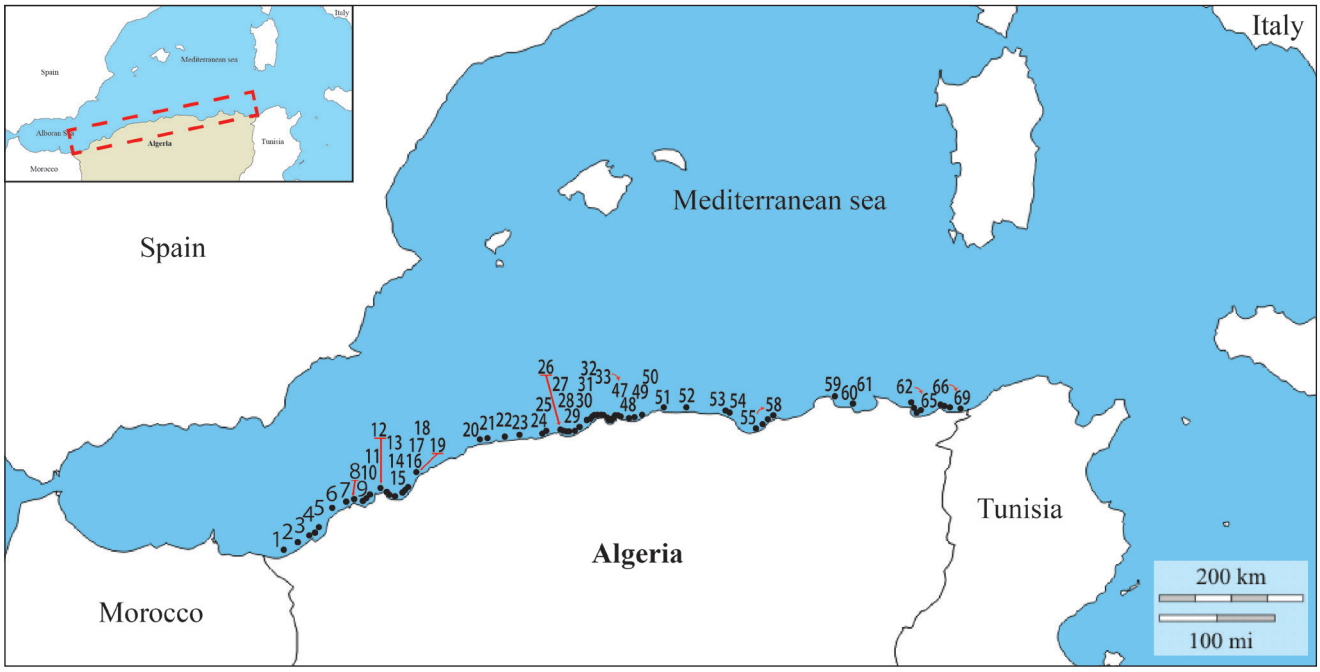


Fig. 1: Location of sites of records (reported from West to East).

Table 1. Coordinates of sampling sites.

Sector	N°	Locality	Latitude	Longitude	Sector	N°	Locality	Latitude	Longitude
1	1	Bay of Ghazaouet	35.111862°	-1.870631°	12	37	Rais Hamidou	36.821081°	3.017627°
	2	Malous	35.244207°	-1.580405°		38	Bologhine	36.813129°	3.035057°
2	3	Rachgoun island	35.317740°	-1.476316°	13	39	Port of Algiers	36.771709°	3.079750°
	4	Beni Saf	35.337830°	-1.409805°		40	Bay of Algiers	36.773393°	3.114887°
	5	Oued El Halouf	35.366730°	-1.275879°		41	Bordj El Kiffane	36.760541°	3.179762°
3	6	Habibas islands	35.723847°	-1.130315°	14	42	Bordj El Bahri	36.786117°	3.219557°
	7	Paloma island	35.770679°	-0.900964°		43	Tamentfoust	36.815101°	3.210601°
	8	Cap Falcon	35.773995°	-0.802511°		44	El Marsa	36.823811°	3.246890°
4	9	Port of Oran	35.719271°	-0.642052°	15	45	Sandja	36.820367°	3.267537°
	10	Gulf of Oran	35.748383°	-0.613843°		46	Surcouf	36.800424°	3.311251°
	11	Kristel	35.824847°	-0.503057°		47	Aguelli Island	36.796664°	3.350405°
5	12	Cap Carbon (Oran)	35.920824°	-0.340679°	16	48	Boudouaou	36.782542°	3.437326°
	13	Port of Arzew	35.854501°	-0.284010°		49	Boumerdes	36.781173°	3.475109°
	14	Port de Bethioua	35.830482°	-0.237130°	17	50	Zemmouri	36.817840°	3.564937°
	15	Mers El Hadjadj	35.813118°	-0.156934°		51	Dellys	36.921962°	3.938339°
6	16	Stidia	35.847278°	-0.013994°	19	52	Azzefoun	36.914405°	4.410933°
	17	Sablette	35.900354°	0.032090°		53	Gouraya	36.782887°	5.093545°
	18	Salamandre	35.927180°	0.042756°		54	Aiguades Bay	36.736105°	5.112339°
	19	Plage du Phare	36.116071°	0.196846°	20	55	Taza	36.709783°	5.530037°
7	20	Sidi Abderrahmane	36.527693°	1.194349°		56	Aouana Island	36.786091°	5.610048°
	21	Ténès	36.536226°	1.306068°		57	Grand Phare	36.821727°	5.689823°
	22	Beni Haoua	36.552110°	1.570225°		58	Jijel	36.831927°	5.757614°
	23	Larhat	36.575259°	1.800279°	21	59	Collo	37.030909°	6.594806°
8	24	Joinville island	36.612851°	2.187556°		60	Stora	36.908229°	6.893586°
	25	Cherchell	36.625234°	2.197721°	22	61	Gulf of Skikda	36.898060°	6.928808°

(continued)

Table 1. Continued

9	26	Chenoua	36.614723°	2.424757°	23	62	Cap de Garde	36.984106°	7.776022°
	27	Tipasa	36.608505°	2.451653°	24	63	Port of Annaba	36.903729°	7.796854°
	28	Golden Horn	36.605970°	2.472628°		65	Sidi Salem	36.872987°	7.809405°
	29	Kouali	36.603996°	2.495389°		64	Bay of Annaba	36.890771°	7.939502°
	30	Ain Tagourait	36.615901°	2.602952°	25	66	Vielle Calle	36.921192°	8.369463°
	31	Bou Ismail,	36.662914°	2.689890°		67	Cap Gros	36.915723°	8.403781°
10	32	Sidi Fredj	36.763865°	2.832934°		68	El Kala	36.917050°	8.439353°
	33	El Djamila	36.795113°	2.884121°		69	Cap Segleb	36.939831°	8.618505°
11	34	Ras Acrata	36.813745°	2.884639°					
	35	Ain Benian	36.819370°	2.923022°					
	36	Bainem	36.823584°	2.970160°					

eration the comments made on species status by Zenetos *et al.* (2017), in particular the distinction between status (alien, cryptogenic, range expansion, vagrant, questionable) and establishment success (casual, established, invasive, unknown). Alien species (synonym: Non-indigenous species (NIS), exotic, non-native, allochthonous), are species present in the wild, introduced outside their natural range and beyond their natural dispersal potential, assisted by Man. Species with no definite evidence of their native or introduced status and species whose probable introduction occurred in "early times" and have not been witnessed are classified as cryptogenic. Questionable species are those with insufficient information, including old casual records that have not been subsequently found despite appropriate investigation, as well as new entries that have not been verified by experts and species with unresolved taxonomic status.

Species with at least two records in the area, spread over time and space (no more than twice for fish) are presumed to be non-established in the area. Invasive species are defined as established aliens that are able to spread away from their area of initial introduction through the production of fertile offspring with noticeable impact, such as threatening the diversity or abundance of native species, the ecological stability of infested ecosystems, economic activities dependent on these ecosystems, and human health. The taxonomy of the species presented in this paper follows WoRMS (WoRMS Editorial board, 2017).

Result and Discussion

List of species and dominant groups

The species introduced along the Algerian coast are presented in four lists (Tables 2a,b,c,d) and classified as true aliens, range expanding, cryptogenic and vagrant species. A total of 70 introduced species have been identified and thereafter allocated to 7 taxonomic groups: Macroalgae, Mollusca, Polychaeta, Crustacea, Bryozoa, Cnidaria and Fish. Almost 3 out of 4 introduced species belong to fish (38.75%) and macrophytes (30%) (Fig. 2a). Crustacea, Polychaeta and Mollusca follow these two groups, with 8, 5 and 4 species respectively and account for approximately 25% of species introduced to Algeria. Cnidaria (3 species) and Bryozoa (1 species) are the least represented groups. True alien species (39 species) and range-expanding species (18) highly dominate the total number of Algeria.

From 1834 to December 2017, 348 sightings of introduced species have been reported in 69 areas scattered along the Algerian coast. Most records (48%) were made in the central subregion of Algeria, followed by the western area (25 %) and the eastern subregion (20%). 26 records (7.6% of the total sightings) were given without a precise location; in particular, certain sightings of *Acanthophora nayadiformis*, *Antithamnion amphigeneum*, *A. boergesenii, Antithamnionella elegans, Asparagopsis armata, Alpheus inopinatus and Glabropilumnus laevis.* The vast majority of sightings (88 % of the total records) belong to Macrophyta (226 records) and Fish 79 records (Fig. 3).

Five alien species, namely *Asparagopsis armata, A. taxiformis, Codium fragile, Caulerpa cylindracea and Lagocephalus sceleratus*, constitute 34.5 % of introduced species sightings along the Algerian coast. Figure 4 illustrates the species that are classified as established along the Algerian coast in decreasing order. It includes all species that have been observed three times or over in more than three areas.

Temporal trend

The rate of Introduced species is following an upward trend since the beginning of 1980s (Fig. 5). This is directly linked to the interest of the scientific community for this component of Algerian marine biodiversity and the plethora of international literature on different aspects related to Introduced species. 63% of the records were made after 2000. All introduced species reported before 1900 (1834-1897) regard macrophytes.

Table 2a. Alien marine species introduced to Algeria with geographic coordinates, origin, locality, year and author of first sighting from 1834 to December 2017 (Abbreviations: YFRA: Year of first record in Algeria, IP: Indo Pacific; P: Pacific; I: Indian Ocean; RS: Red Sea; At: Atlantic; Tr: Tropical; Circ: Circumtropical; Est: Established; Ques: Questionable; Cas: Casual; Inv: Invasive; E: East; W: West; N: North; S: South & NIA: Non identified Area).

Species	Group	YFRA	Coordinates	Origin	Locality	Authors	Success
Antithamnion amphigeneum A.J.K.Millar	Macrophyta	1989	36.773393; 3.114887°*	SW. P	*Algiers*	Verlaque & Seridi, 1991 as *A. algeriensis*	Cas
Asparagopsis armata Harvey	Macrophyta	1923		SW. P	NIA	Sauvageau, 1925	Inv
Asparagopsis taxiformis (Delile) Trevisan de Saint-Léon	Macrophyta	1939	36.786117°; 3.219557°*	At-IP	Bordj El Bahri	Feldmann & Feldmann, 1939	Inv
Bonnemaisonia hamifera Hariot	Macrophyta	1967	6.921962°; 3.938339°*	IP	Dellys	Boudouresque, 1969 as *Trailliella intricata*	Est
Caulerpa cylindracea Sonder	Macrophyta	2005	36.800424°; 3.311251°* 36.760541°; 3.179762°*	IP	Surcouf Bordj El Kiffan	Ould Ahmed & Meinesz 2007 as *C. racemosa* var. *cylindracea*	Inv
Codium fragile (Suringar) Hariot	Macrophyta	1990	36.800424°; 3.311251° * 36.782542°; 3.437326°*	NW. P	Surcouf - Boudouaou	Seridi, 1990	Est
*Colaconema codicola (*Borgesen) H. Stegenga, J.J. Bolton and R.J. Anderson	Macrophyta	1990	36.773393°; 3.114887°*	NE. At	Algiers	Seridi, 1990	Cas
Colpomenia peregrina Sauvageau	Macrophyta	1967	36.823811°; 3.246890°*	IP	El Marsa	Boudouresque & Boudouresque, 1969	Cas
*Griffithsia corallinoides (*Linnaeus*)* Trevisan	Macrophyta	1834	36.890771°; 7.939502°*	At/P	Annaba	Steinheil, 1834 as *Ceramium corallium*	Est
Hypnea spinella (C.Agardh) Kützing	Macrophyta	1990	36.608505°; 2.451653°*	Pantr	Tipasa	Seridi, 1990 as *H. cervicornis*	Cas
Lophocladia lallemandii (Montagne) F. Schmit	Macrophyta	1938	36.823811°; 3.246890°*	IP	El Marsa	Feldmann & Feldmann, 1938	Cas
Melanothamnus harveyi (Bailey) *Díaz-Tapia & Maggs*	Macrophyta	1990	36.773393°; 3.114887°*	NW. P	*Algiers*	Seridi, 1990 as *Polysiphonia mottei*	Cas
Pachymeniopsis lanceolata (K. Okamura) Y.Yamada ex S. Kawabata	Macrophyta	2003	36.760541°; 3.179762°*		Bordj El KIffan	Seridi, 2007 as *ex Grateloupia*	Cas
Mercenaria mercenaria (Linnaeus, 1758)	Mollusca	1994	35.723847; -1.130315°*	W. At	Habibas islands	Grimes & Kaidi, 1995	Est
Pinctada imbricata radiata (Leach, 1814)	Mollusca	2010	36.917050°; 8.439353°	IP /RS	El Kala	Refes, 2012	Cas
Bursatella leachii Blainville, 1817	Mollusca	2008	36.762500°; 2.838889°	Circ	Sidi Fredj	Lamouti & Bachari in Eleftheriou et *al.*, 2011	?
Lumbrineris perkinsi Carrera-Parra, 2001	Polychaeta	<1990	?		Gulf of Skikda	Bakalem, 2008 as *Lumbrineris inflata* Moore, 1911	Que
Ficopomatus enigmaticus (Fauvel, 1923)	Polychaeta	1997	36.898060°; 6.928808°*	?	Gulf of Skikda	Grimes, 2010	Cas
Metasychis gotoi (Izuka, 1902)	Polychaeta	1997	35.748383°; -0.613843°*	IP	Gulf of Oran		?
Notomastus aberans Day, 1957	Polychaeta	1997	35.748383°; -0.613843°*	I/RS	Gulf of Oran		Cas
Pista unibranchia Day, 1963	Polychaeta	1984	36.773393°; 3.114887°		Bay of Algiers	Bakalem, 2008	Cas
Alpheus inopinatus Holthuis & Gottlieb, 1958	Crustacea	1999	35.111861°; -1.870631°*	I/RS	Gulf of Ghazaouet	Grimes *et al.*, 2016	?
Alpheus rapacida de Man, 1908	Crustacea	1997	35.748383°; -0.*613843*°*	I-W.P	Gulf of Oran	Grimes et *al.*, 2016	Cas
Eocuma sarsii (Kossmann), 1880	Crustacea	???	35.103788°;-1.863989°		Arzew harbour	Grimes, 2010	Cas
Glabropilumnus laevis (Dana, 1852*)*	Crustacea	1999	35.111861°; -1.870631°*	I	Gulf of Ghazaouet	Grimes *et al.*, 2016	?
Megabalanus tintinnabulum (Linnaeus, 1758)	Crustacea	1996	36.890771°; 7.939502°		Bay of Annaba	Grimes, 2010	Que
Percnon gibbesi (H. Milne Edwards, 1853)	Crustacea	2010	37.0252°; 6.5574°	W. At	Collo Skikda	Bouzaza *in* Katsanevakis *et al.*, 2011	Est

(continued)

Table 2a. Continued

Penaeus japonicus Spence Bate, 1888	Crustacea	2004	?		Chlef	Massuti *et al.*, 2004	Est
Amathia verticillata (delle Chiaje, 1822)	Bryozoa	2016	35.317740°; -1.476316°	IP	Rachgoun island	Ramos *et al.*, in PNUE/ PAM-CAR/ASP, 2016	Est
Clytia linearis (Thorneley, 1900)	Cnidaria	1955	36.662914°; 2.689890°*		Bou Ismail Bay	Picard, 1955	Cas
Eucheilota paradoxica Mayer, 1900	Cnidaria	2013			Sidi Fredj	Kherchouche-Ait Ouadour, 2014	Cas
Acropoma japonicum Günther, 1859	Fish	2011	36.946597°; 7.770472° 36.933864°; 7.763475°	IP	Gulf of Annaba	Hannachi, 2015 Hannachi *et al.*, 2015	Cas
Atherinomorus forskali (Rüppell, 1838)	Fish	2004	36.662914°; 2.689890°*		Bou Ismail Bay	Massuti *et al.*, 2004	Cas
Etrumeus golanii DiBattista, Randall & Bowen, 2012	Fish	2017	36.6222°; 2.2325°		Cherchell	Kassar & Hemdia, 2017 in Stamouli et al., 2017	Cas
Fistularia commersonii Rüppell, 1838	Fish	2008	36.898060°; 6.928808°*	IP	Gulf of Skikda	Kara & Oudjane 2009	Est
Hemiramphus far (Forsskål, 1775)	Fish	2010	37.030909°; 6.594829°	IP	Collo	Kara *et al.*, 2012	?
Lagocephalus sceleratus (Gmelin, 1789)	Fish	2012	NIA	IP	Algeria	Refes & Semahi, 2014	Est
Pomadasys stridens (Forsskål, 1775)	Fish		?		Algeria	Chalabi, 1999	Cas
Siganus luridus (Rüppell, 1829)	Fish		?		Algeria	Chalabi, 1999	Cas

***** Allocated approximate geographical position (sea Table 1) based on localityor zone of records by the author(s).

Table 2b. Range-expanding species introduced to Algeria. YFRA: Year of first record in Algeria, Origin: At: Atlantic; Tr: Tropical; Circ: Circumtropical; Success: Est: Established; Cas: Casual, ?: unknown.

Species	Group	YFRA	Coordinates	Origin	Locality	Authors	Success
Taningia danae Joubin, 1931	Mollusca	2003	35.738400°; -1.353433°	IP.P	Bench of Alidade - Habibas islands	Quetglas *et al.*, 2006	*?*
Acanthurus monroviae Steindachner, 1876	Fish	2001	36.662914°; 2.689890°*	Tr. At	Bou Ismail Bay	Hemida *et al.*, 2004 a	Cas
Dicologlossa hexophthalma (Bennett, 1831)	Fish	2004	35.8588°; -0.1275°	RE	Gulf of Arzew	Massuti *et al.*, 2004	Cas
			36.662914°; 2.689890°*		Bou Ismail Bay	Massuti *et al.*, 2004	
Ephippion guttifer (Bennett, 1831)	Fish	1933	36.536226°; 1.306068°*		Ténès	Dieuzeide, 1933	?
Halosaurus ovenii Johnson, 1864	Fish	1960	36.625234°; 2.197721°*	Tr. At	Cherchell	Dieuzeide, 1963	Cas
Hyperoglyphe perciformis (Mitchill, 1818)	Fish	2015	36.800424°; 3.311251°*		Surcouf	M. Benabdi, personal communication, 2015	?
Mobula japanica (Müller & Henle, 1841)	Fish	2016	NIA		Algiers	Hemida *et al.*, 2016	Cas
Pagellus bellottii Steindachner, 1882	Fish	1960	NIA	Tr. At	Algiers	Dieuzeide, 1960	Cas
Pisodonophis semicinctus (Richardson, 1848)	Fish	1954	36.625234°; 2.197721°*	Tr. At	Cherchell	Dieuzeide & Roland, 1957	Cas
Psenes pellucidus Lütken, 1880	Fish	1955	36.662914°; 2.689890°*	Tr. At	Bou Ismail Bay	Dieuzeide & Roland, 1955	Cas
Urogymnus asperrimus (= Raja africana) Bloch & Schneider, 1801	Fish	2007	NIA		Algiers	Hemida *et al.*, 2007	Cas
Solea senegalensis Kaup, 1858	Fish	1979	36.890771°; 7.939502°*	Tr. At	Gulf of Annaba	Alili & Marinaro, 1986	Est
			36.917050°; 8.439353° *		El Kala		
Sphyraena viridensis Cuvier, 1829	Fish	2003	36.890771°; 7.939502°*		Gulf of Annaba	Kara & Bourehail, 2003	Cas
Sphoeroides pachygaster (Müller & Troschel, 1848)	Fish	2009	?	Tr. At	Chetaïbi-Seraidi	Hemida *et al.*, 2009	Cas
Symphurus ligulatus (Cocco, 1844)	Fish	2003	NIA		Algeria	Massuti *et al.*, 2003	Cas

(continued)

Table 2b. Continued

Gephyroberyx darwinii (Johnson, 1866)	Fish	1955	36.625234°; 2.197721°*		Cherchell	Dieuzeide & Roland, 1958	Cas
Trachyscorpia cristulata echinata (Köhler, 1896)	Fish	1982	35.111861°; -1.870631°*	Tr. At	Gulf of Ghazaouet	ISTPM, 1982	?
Galeoides decadactylus (Bloch, 1795)	Fish	1927	35.748383°; -0.613843°*		Gulf of Oran	Dieuzeide, 1927	

***** Allocated approximate geographical position (sea Table 1) based on localityor zone of records by the author(s)

Table 2c. List of cryptogenic species introduced to Algeria. YFRA: Year of first record in Algeria, Origin: IP: Indo Pacific; P: Pacific, At: Atlantic; Tr: Tropical; Circ: Circumtropical; Success: Est: Established Cas: Casual; ?: Unknown.

Species		**YFRA**	**Coordinates**	**Origin**	**Locality**	**Authors**	**Success**
Acanthophora nayadiformis (Delile) Papenfuss	Macrophyta	1990	36.763865°; 2.832934° * 36.608505° 2.451653°*	IP	Sidi Fredj and Tipasa	Seridi, 1990	Est
Anotrichium furcellatum (J. Agardh) Baldock = *A. okamurae* Baldock	Macrophyta	<1900	NIA	P	Algiers	Durieu *in* Feldmann-Mazoyer & Meslin, 1939 as *A. furcellatum*	Cas
Antithamnionella boergesenii (Cormaci & G.Furnari) Athanasiadis	Macrophyta	1937	36.771709°; 3.079750°*	IP	*Port of Algiers*	Mazoyer & Feldmann, 1937 as *A. elegans*	Cas
Antithamnionella elegans (Berthold) J.H.Price et D.M.John	Macrophyta	1936	36.773393°; 3.114887°* 36.786117°; 3.219557°*	?	Algiers	Mazoyer & Feldmann, 1937	Est
Caulerpa chemnitzia (Esper) J. V. Lamouroux	Macrophyta	2011	NIA	IP	Algiers	Lamouti *in* Verlaque *et al.,* 2015	Cas
Chondria coerulescens (J. Agardh) Falkenberg	Macrophyta	1893	*NIA*	At.E	Oran	Debray, 1893	Est
Polysiphonia atlantica Kapraun & J.N.Norris	Macrophyta	?	?	N.At-N.P	Algeria	Verlaque *et al.*, 2015	?
Bugulina stolonifera (Ryland, 1960)	Bryozoa	1955	36.662914°; 2.689890°*	IP	Bou Ismail Bay	Gauthier, 1955 as *Bugula avicularia*	Cas
Ulva lactuca Linnaeus	Macrophyta	1834	36.773393°; 3.114887°*	IP	Algiers	Steinheil (1834) Montagne, 1846 as *U. fasciata*	Cas
Elasmopus pectenicrus (Spence Bate, 1862)	Crustacea	<1990	36.773393°; 3.114887°*		Algiers	Bakalem & Dauvin, 1992	Cas
Oculina patagonica de Angelis, 1908	Cnidaria	2005	35.723847; -1.130315°	SW. At	Habibas islands	Sartoretto *et al.,* 2008	Est

***** Allocated approximate geographical position (sea Table 1) based on localityor zone of records by the author(s)

Table 2d. List of vagrant species introduced to Algeria.

Species		**YFRA**	**Coordinates**	**Origin**	**Locality**	**Authors**
Carcharhinus altimus (Springer, 1950)	Fish	2001	NIA	IP. E	Algiers	Hemida & Labidi, 2001
Carcharhinus falciformis (Müller & Henle, 1839)	Fish	2001	NIA	Circ	Eastern Algeria	Hemida & Labidi, 2001

Phytobenthos

During the last 20 years the number of Macrophyta records in the Mediterranean has increased from 61 to 133 species (Fig. 6).

Thirteen alien species belonging to macroalgae have been recorded along the Algerian coast, 10 Rhodophyta, 2 Chlorophyta and 1 Ochrophyta; this is less than the 27 alien marine macrophytes recorded in Tunisia (Sghaier *et al.*, 2016) and equal to those reported for Libya (Bazairi *et al.,* 2013).

According to Ould Ahmed *et al.* (2013), Algerian Phaeophyceae are characterized by a high number of cosmopolitan or Sub-cosmopolitan taxa (31 taxa, 35.6%), followed by Mediterranean (25 taxa, 28.7%), Atlantic (20 taxa, 23%) and Indo-Atlantic taxa (9 taxa, 10.3%). Circumboreal and Circumtropical taxa are scarcely represented (2 taxa each, 2.3%). Some distribution details for the most invasive macroalgae, namely, *Caulerpa cylindracea, Asparagopsis armata* and *Asparagopsis taxiformis* are presented below.

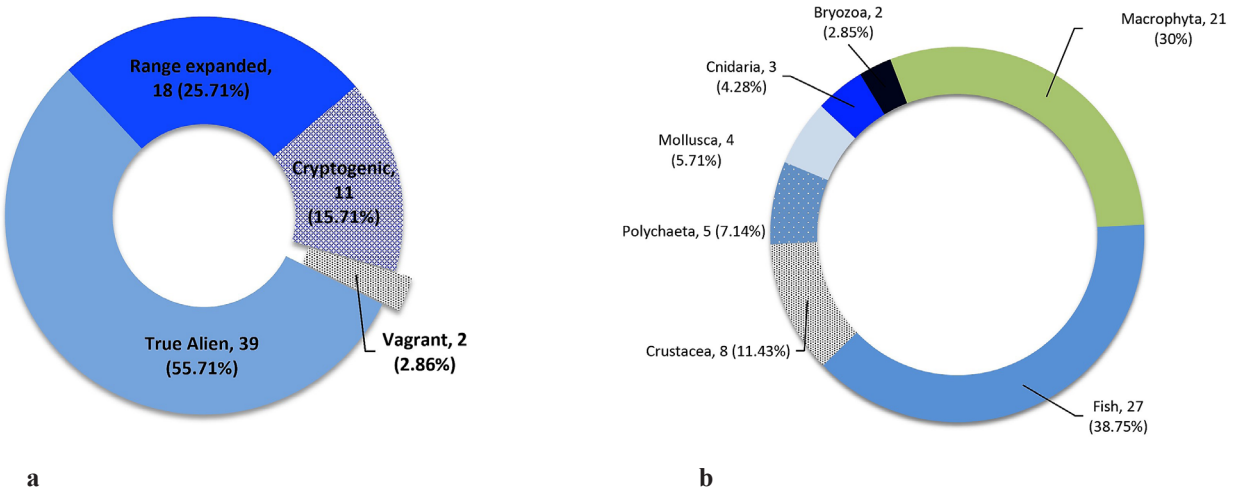


Fig. 2: Composition and taxonomic distribution of Algerian introduced species.

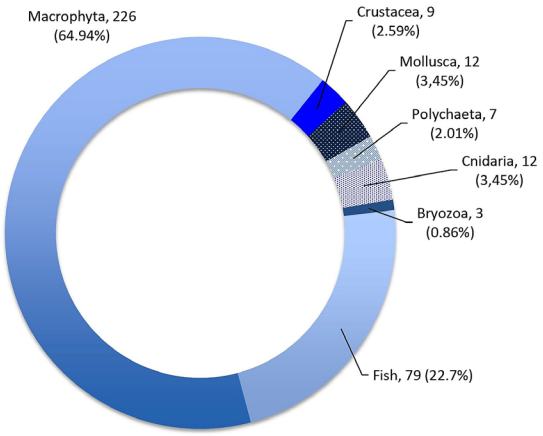


Fig. 3: Taxonomic distribution of introduced species sightings along the Algerian coast.

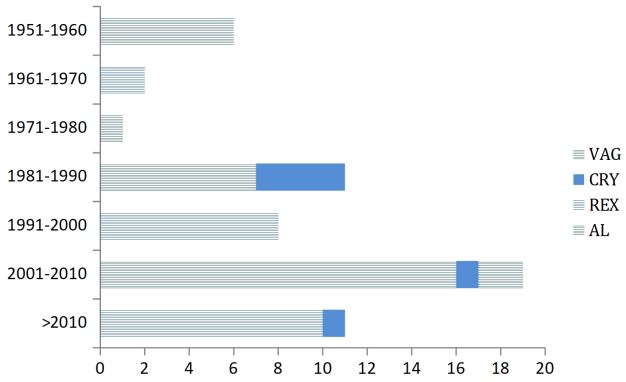


Fig. 5: Temporal trends in Introduced species along the Algerian Coast (from 1834 to 2017). AL (alien), CRY (cryptogenic), REX (range expansion), VAG (vagrant).

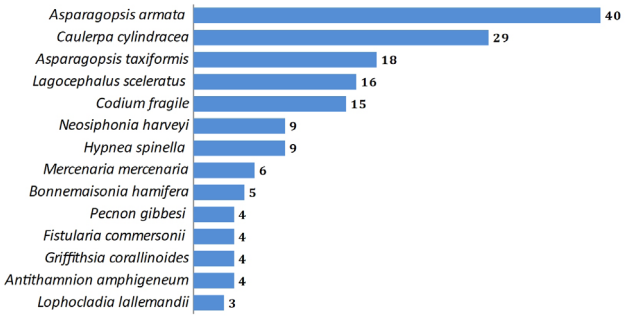


Fig. 4: Introduced species sightings for species that have been observed more than three times.

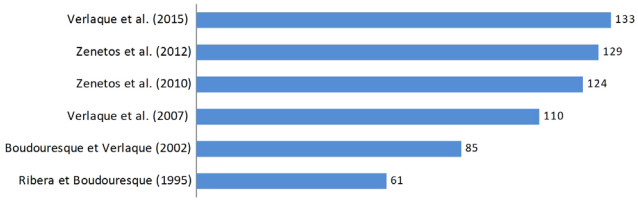


Fig. 6: Number of alien macrophytes reported in the Mediterranean Sea.

Caulerpa cylindracea was first found in Tunisia under the name of *Caulerpa racemosa* (Ben Maiz *in* Hamza *et al.*, 1995) and since then it has been spreading rapidly to the rest of the Mediterranean basin, probably through shipping (Verlaque *et al.*, 2003), occupying diverse substrata at various depths (Verlaque *et al.*, 2015). *Caulerpa cylindracea* was first observed in Algeria in 2005, at three separate but close areas (Sidi Fredj, Bou Ismail, Tamentfoust) in the central sector of the Algerian coast and reported under the name of *Caulerpa racemosa* (Forsskål) J. Agardh by Ould Ahmed & Meinesz (2007). Until recently, the species was accepted as *Caulerpa*

racemosa var. *cylindracea* (Sonder) Verlaque, Huisman and Boudouresque, but it is now reinstated to its species rank as *C. cylindracea* Sonder (Guiry & Guiry, 2017). Since 2007, *C. cylindracea* has become recurrent and has displayed rapid progression. Seridi (2007) mentioned its presence at two localities in Algiers (Sidi Fredj in the west and Bordj El Kiffan in the east). According to Seridi and Kabrane (2010), *C. cylindracea* is present in the central region, from west to east. The seaweed was found at Sidi Fredj, Rais Hamidou, Bainem, Port of Algiers, Bordj El Kiffan, Tamentfoust and Aguelli Island. This species is also present in Tipasa (Seridi, 2013). All the collected specimens had the same appearance with irregularly branched and interlocking stolons attached to the substrates by colourless rhizoids. *C. cylindracea* has widely extended its range since its first report and occupies large areas, particularly along the western and central Algerian coast (Table 3). *C. cylindracea* has been observed at different depths (0-37 m), on various habitats (sand, mud, rock, mixt), in both polluted and unpolluted areas, revealing a strong capacity to adapt and important invasive behaviour (Ould Ahmed & Meneisz, 2007; Seridi, 2007; Seridi & Kabrane, 2010; Lamouti *et al.*, 2011; Bentaallah & Kerfouf, 2013; Aouissi *et al.,* 2013; Bachir Bouiadjra *et al.*, 2011; Lamouti & Bachari, 2011 and Hussein, 2015). The first observation of this species on the western coast of Algeria was reported by Bachir Bouidjra *et al.* (2010), at Mostaganem (Salamandre and Stidia) on sand and rock substratum (0.5-2m depth), associated with *Corallina elongata* and *Ulva lactuca* Linnaeus, thus indicating poor to bad coastal water quality (Arévalo *et al.*, 2007). The appearance of the invasive algae *C. cylindracea* in Mostaganem is mostly due to heavy maritime traffic in this area, which is very close to Arzew harbour (petrochemical, industrial and fishery). This suggests the tolerance of *C. cylindracea* to high pollution levels, as reported by Bachir Bouiadjra *et al.* (2010). According to these authors, Salamandre and Stidia are exposed to winds, strong waves and important hydrodynamic flow, due to the prevailing west to south-west winds and east to north-east winds (ONM, 2009) that facilitate the dispersion of *C. cylindracea* to the gulf of Arzew. In addition,

Table 3. Location of *Caulerpa cylindracea* along the Algerian coast.

Locality	Coordinates	Date of observation	Depth (m)	Bottom type	Source
East					
Bay of Annaba (Cap de Garde)	36.984106°; 7.776022° *	2012	25	Sand	Aouissi *et al.*, 2013
Centre					
Aguelli Island (Alger)	36.794167° ; 3.351389°	2009-2010	13	Rock, Sand	Lamouti, 2006; Lamouti *et al.*, 2011
Tamentfoust (Alger)	36.815101°; 3.210601° *	2005-2009-2010	10 -22	Mud, sand	Lamouti *et al.*, 2011
Tamentfoust (Alger)	36.808056° ; 3.231111°	2005	0,5		Ould Ahmed & Meinesz, 2007
Bordj El Bahri (Alger)	36.786117°; 3.219557°*	2007	<1	Rocky	Seridi, 2007
Bordj El Kiffan (Alger)	36.760541°; 3.179762°*	2007			Seridi, 2007
Rais Hamidou (Alger)	3636.821081°; 3.017627°*	2006-2007	1-17 & 29	Sand Rocky, Posidonia	Lamouti *et al.*, 2011
Bainem (Alger)	36.823584°; 2.970160°*	2006	6	Rocky, Posidonia	Lamouti *et al.*, 2011
El Djamila (Alger)	36.795113°; 2.884121°*	2006	8		Lamouti *et al.*, 2011
Sidi Fredj (Alger)	36.763865°; 2.832934°*	2005-2011	0.5-12	Rocky, mud Posidonia, sand	Lamouti, 2006, Ould Ahmed & Meinesz, 2007, Seridi, 2007, Lamouti *et al.*, 2011 ; Refes, unpublished
Bou Ismail (Tipasa)	36.662914°; 2.689890°*	2005- 2006-2007	<1	Rocky	Lamouti *et al.* (2011), Ould Ahmed & Meinesz, 2007
Tipasa	36.608505°; 2.451653°*	2005-2013	<1	Rocky, Pos.	Seridi, 2013

(continued)

Table 3. Continued

West					
Plage du Phare (Mostaganem)	36.116071°; 0.196846°*	2009	<2	Rocky	Bachir Bouiadjra *et al.*, 2011
Salamandre (Mostaganem)	35.920000° ; 0.057778° 35.919722° ; 0.057778° 35.918889° ; 0.057500° 35.918333° ; 0.057500°	2009	0.5-0.8 <2	Sand, rocky	Bachir Bouiadjra *et al.*, 2011
Sablette (Mostaganem)	35.900354°; 0.032090°*	2009	<2	Sand	Bachir Bouiadjra *et al.*, 2011
Stidia (Mostaganem)	35.847278°; -0.013994°*	2009	<2	Sand, rocky	Bachir Bouiadjra *et al.*, 2011
Mers El Hadjadj	35.813118°; -0.156934°*	2010-2011	29		Bentaallah & Kerfouf, 2013
Cap Carbon	35.920824°; -0.340679°*	2010-2013		Rocky	Hussein, 2015
Paloma Island	35.770679°; -0.900964°*	2014	0-37		Hussein, 2015

the Stidia site is a small fishing harbour where fishermen clean their nets, sometimes charged with algae, including *C. cylindracea* (Bachir Bouiadjra *et al.*, 2010). In Eastern Algerian waters, *C. cylindracea* has been identified in the Bay of Annaba (Eastern Algeria) with an important depth range (15-27m)on soft and hard substratum (Aouissi *et al.*, 2013). According to Lamouti (2006), a mapping campaign for *C. cylindracea* was carried out on the west beach of Sidi Fredj from the 11th to the 15th of April 2010 and from the 21st to the 29th of April 2010, which showed that this species had colonised 5.09% of the total survey area (628 GPS points); 71.87% of this algae covers the soft substrates while 28.12% has colonised the bedrock. It is distributed from the surface to 2.8m depth, thus revealing an increase in the distribution of the species compared to July 2006. The last records of this species have been made near Paloma Island, not far from the Alboran Sea, on the west coast of Algeria, at 37m depth, and Cap Carbon, on the eastern coast of Oran (Hussein, 2015). According to Hussein (2015), *C. cylindracea* was found at Cap Carbon, with *Asparagopsis armata* and *Asparagopsis taxiformis*, from 0.5 to 5.0 m of depth, associated with *Cystoseira amentacea* in photophilic algae of the upper infralittoral.

Several studies dealing with the impact of *C. cylindracea* on macrophyte assemblages (rocky substrate, dead *Posidonia oceanica* mats, coralligenous and detritic assemblages) have been conducted and indicate a decrease in the total number of species and total macrophyte coverage when *C. cylindracea* is present (Ceccherelli *et al.*, 2001; Piazzi *et al.*, 2001; 2005; Balata *et al.*, 2004; Klein & Verlaque, 2008; Antolić *et al.,* 2008; Bachir Bouiadjra *et al.*, 2010). *C. cylindracea* displays important growth potential that appears to be favoured by moderately high water temperatures (about 20°C) and waters loaded with organic matter (Seridi & Kabrane, 2010). Observations show that the *Posidonia* meadows are impacted by *C. cylindracea* expansion. The authors highlighted a similar impact to that described in the literature, such as regression of other algal species when *C. cylindracea* increases its spatial coverage. This species has also been recognized in various unpolluted environments, such as the National Parc of Port-Cros and the Natural Reserve of Bouches de Bonifacio, with wide bathymetric distribution from supralittoral puddles to 90m depth (Cottalorda *et al.*, 2008). Several studies expect an increasing impact of *C. Cylindracea* on the marine biodiversity of invaded Mediterranean ecosystems. The trophic relationships among alien marine organisms as well as between alien and native species in a marine area could be one of the driving forces of the adaptation mechanisms of bio-invaders. A recent study conducted by the National High School of Marine Sciences and Coastal Management showed clearly that *Caulerpa cylindracea* has impacted the structure of coastal biodiversity since its first record at Sidi Fredj in 2005 (Bahri and Refes, unpublished data). The data of this preliminary survey reflect the possible impacts of C. *cylindracea* invasion on benthic assemblages. It was clearly established that in the presence of *C. cylindracea*, the biomass of *Cymodocea nodosa* decreased between June 2010 and December 2010, which confirms the conclusions of Ceccherelli & Campos (2002).

Two species of *Asparagopsi*s are considered introduced to the Mediterranean Sea (Boudouresque & Verlaque, 2002). *Asparagopsis armata* (Fig. 7a), a species of Southwestern Pacific origin, is widespread in the Mediterranean (Verlaque *et al.*, 2015). Verlaque (1994) considers *A. armata* as one of the classic examples of introduction of exotic algae to Europe. *A. armata* is mainly recorded along western Mediterranean coasts (South & Tittley, 1986), where it is regarded as invasive (Boudouresque & Verlaque, 2002) being first found in Algeria in 1923 (Sauvageau, 1925). It is now frequent and widespread in the western Mediterranean. *A. armata* is present on the western, central and eastern shores of Algiers (Hamel, 1926). Since 2003, this species has been reported

from several areas and habitats along the Algerian coast (ISMAL, 2003; Semroud *et al.*, 2004; Grimes, 2008; Sartoretto *et al.,* 2008; Aouissi *et al.*, 2013; Seridi, 2013; Hussein, 2015; Ould Ahmed, 2015) (Fig. 7b).

Asparagopsis taxiformis Harvey, 1855 abounds in tropical and warm-temperate parts of the Atlantic and Indo-Pacific (Bonin & Hawkes, 1987; Andreakis *et al.*, 2004). *Asparagopsis taxiformis* was observed from 1 to 30m at Habibas Islands (Western Algeria) (Sartoretto *et al.*, 2008). Bachet *et al.* (2007) have observed this algae at several stations of Habibas islands (Fig. 8a) from 6-43 m depths, associated with *Alcyonium acaule, Marthasterias glacialis, Chondrosia reniformis, Holothuria sanctori*. The most abundant species introduced to Habibas islands is *Asparagospsis taxiformis*, but it seems to be well-integrated in the infralittoral rocks community, up to the upper coralligenous level, and is a major component of the landscape. It cohabits in some places with *Asparagopsis armata*, but this appears to be less frequent (Bachet *et al.*, 2007). *Asparagopsis taxiformis* was also found at Aouana Island (Eastern Algeria) (Grimes, 2008) and three sites on the western coast of Algiers (Tipasa, Chenoua and Kouali) (Seridi, 2013) (Fig. 8b). This species was recently recorded at Cherchell, Chenoua, Ain Tagourait and Ain Benian (Ould Ahmed, 2015). All these recent records have been made in the central zone of Algerian waters.

According to (PNUE/PAM-CAR/ASP, 2016), the Rhodophyta *A. taxiformis* is abundant in the infralittoral photophile algae community of the North sector of Rachgoun Island (western Algerian coast, at the eastern limit of the Alboran sea), at 0- 15m of depth, covering an important surface and could be considered as invasive in this area. According to Benabdi (2015), this species has been observed from 1 to 30m depth at Cap de Garde (Annaba) on the eastern Algerian coast. *A. armata and A. taxiformis* has also been reported in Algiers (from Marsa to Aguelli) (CAR/ASP-PNUE/PAM, 2015).

Verlaque *et al.* (2015) highlight two separate introductions of *Asparagopsis taxiformis* to the Mediterranean, one by shipping and the other via the Suez Canal. The species is now widely distributed in the Mediterranean. In many cases, taxonomic identifications are based solely on the morphologically similar '*Falkenbergia'* stages (Diapoulis & Verlaque, 1981). A taxon described in 1813 from Alexandria by Delile and confined to the eastern Mediterranean basin (Egypt, Lebanon, Syria and likely Libya) (Ní Chualaín *et al.*, 2004) and the other one, recently introduced to western Mediterranean basin, and described as invasive in Algeria, the Balearic Islands,

Fig. 7a: *Asparagopsis armata* at Habibas Islands (photo credit: May 2007, J.G. Harmelin).

Fig. 8a: *Asparagopsis taxiformis* associated with *Astroides calycularis* at Habibas islands (photo credit: May 2007, J.G. Harmelin).

Fig. 7b: Distribution of *Asparagopsis armata* along the Algerian Coast.

Fig. 8b: Distribution of *Asparagopsis taxiformis* along the Algerian Coast.

Villefranche-sur-mer (France) and Sicily in western Italy (Ní Chualaín *et al.*, 2004). Molecular analysis showed that the first taxon appears to be of Atlantic origin, via the Strait of Gibraltar, whereas the second taxon probably colonized the Mediterranean from the Indo-Pacific, most likely via the Suez Canal (Andreakis *et al.*, 2004, Ní Chualaín *et al.*, 2004). As reported by Ould Ahmed (2015), *A. taxiformis* was described for the first time in Algeria under the name of *Fucus taxiformis* Delile in Bordj El Bahri (centre of Algerian coast).

Lophocladia lallemandii was identified for the first time along the Algerian Coast by Feldmann & Feldmann (1938) in El Marsa. *L. lallemandii* was seemingly introduced to the Mediterranean (Verlaque *et al.*, 2015) via shipping and the Suez Canal, probably to multiple locations, where it exhibited invasive behaviour. It was first found in Piraeus, Greece, in 1908. This species originates from the Indian Pacific region (Ballesteros *et al.*, 2007). According to Gómez Garreta *et al.* (2001), *L. lallemandii* was also reported in Algeria by Perret-Boudouresque & Seridi (1989). *L. lallemandii* was recently recorded by Ould Ahmed (2015) in Mers El Hadjadj, on the western part of the Algerian coast directly exposed to Atlantic waters (Fig. 9).

Antithamnionella elegans was reported in Algeria in 1936 along the central and eastern Algerian coast (Algiers and Bejaia) (Feldmann-Mazoyer, 1936; Mazoyer & Feldmann, 1937). Seridi (2007) reported the casual presence of this species in Alger plage (east of Algiers). More recently, *A. elegans* was reported by Ould Ahmed (2015) in Arzew and Sidi Fredj (Fig. 9). In their description of the harvested specimen from the port of Algiers, along Agha pier in 1937, Mazoyer & Feldmann (1937) highlighted the difficulty to distinguish *Antithamnion* and *Antithamnionella*.

Antithamnion amphigeneum, a species of Indo-Pacific affinity (Verlaque, 1994), was reported for the first time in Algeria by Verlaque & Seridi (1991), under the name of *Antithamnion algeriensis* and also along the Algerian Coast by Athanasiadis, 1996; Gómez Garreta *et al.,* 2001; Cormaci *et al.*, 2004. This algae was probably introduced to the Mediterranean (Algeria and Spain) from the east coast of Australia (Athanasiadis, 1996) by shipping (Verlaque *et al.,* 2015).

Antithamnionella boergesenii was recorded in Algeria by Mazoyer & Feldmann (1937). This species was probably introduced to the Mediterranean (Verlaque *et al.*, 2015) by shipping.

Bonnemaisonia hamifera (Trailliella intracata) was reported as *Trailliella intricata* in El Marsa (centre) and Dellys (East) by Boudouresque (1969). *Bonnemaisonia hamifera was* recorded by Ould Ahmed (2015) at Habibas islands, Kouali and Bou Ismail (Fig. 9).

Chondria coerulescens was reported for the first time on the western coast of Algeria, in Oran by Debray (1893). It was also reported by G. Feldmann (1949) in Tipasa and in Bologhine and les Deux Moulins, close to Algiers. *Chondria coerulescens* was recorded recently by Ould Ahmed (2015) in Arzew (western Algeria) and in the marine part of the National Park of Taza (Eastern Algeria).

Griffithsia corallinoides has been sighted along the Algerian coast and the first record was reported from Annaba by Steinheil (1834) who described it as *Ceramium corallium* Bory. *Griffithsia corallinoides* has been recorded by Montagne (1938) based on specimens sampled in

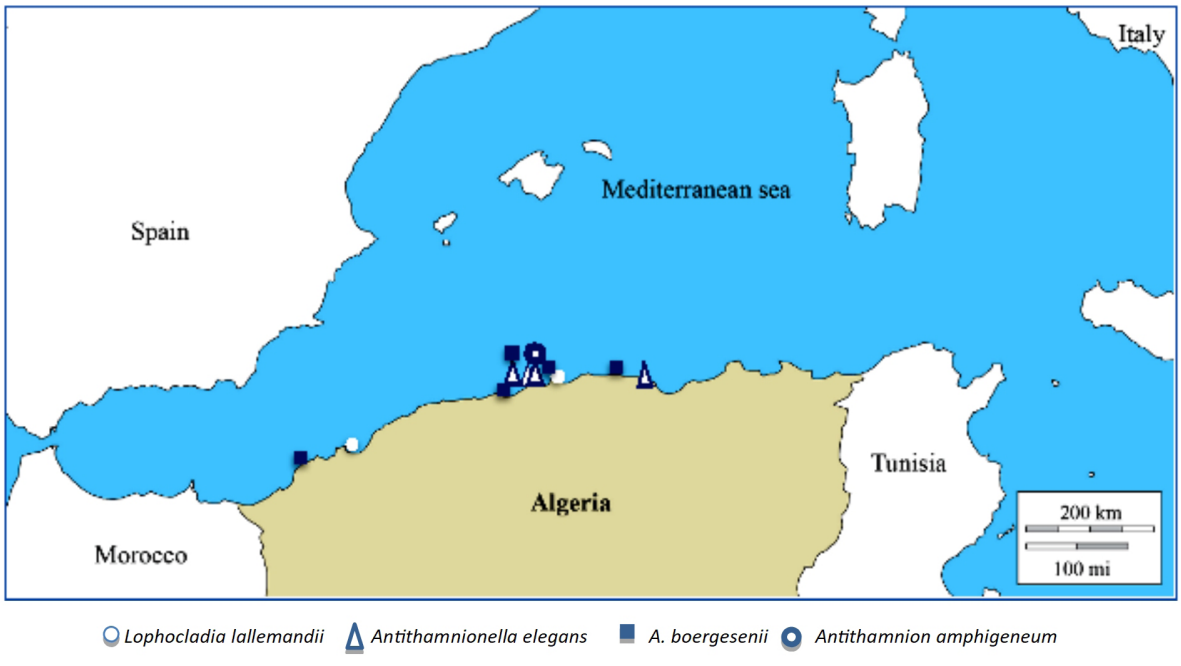


Fig. 9: Distribution of *Lophocladia lallemandii, Antithamnionella elegans, A. boergesenii* and *Antithamnion amphigeneum* along the Algerian coast.

Algiers by Roussel. More recently, this species has been identified by Ould Ahmed (2015) in Sidi Fredj (centre of Algeria) as an epiphyte of *Caulerpa cylindracea.*

Hypnea spinella (= Hypnea cervicornis) was reported for the first time in Algeria in Tipasa by Seridi (1990). This species has also been observed and reported in Annaba (Aouissi *et al.,* 2013) and more recently by Ould Ahmed (2015) in several other zones of the Algerian coast: Habibas islands, Cherchell, Ain Benian, Ain Tagourait, Bou Ismail and National Park of Taza.

Colpomenia peregrina (Sauvageau) Hamel (= *C. sinuosa* (Mertens ex Roth) Derbès and Solier in Castagne *var. peregrina* Sauvageau) was first reported along the Algerian coast by Boudouresque & Boudouresque (1969) in El Marsa (Central coast). It is now widespread in the Mediterranean (Verlaque *et al.*, 2015). This species has an Indo-Pacific origin and has been found in Sidi Fredj in 1 m depth, in a *Caulerpa cylindracea* meadow (Ould Ahmed *et al.*, 2013). *Colpomenia peregrina* was first introduced via the Pacific oyster *Crassostrea virginica* and then spread through the currents. Its expansion is favoured by the absence of predators and its high rate of growth.

Codium fragile was reported for the first time in Algeria in Surcouf (center) by Seridi (1990) and also from the National Park of El-Kala (Semroud *et al.*, 2004). Bachet *et al.* (2007) found *Codium fragile* at Habibas Island (Fig. 10a), at 20m depth on flat bedrock, associated with the red algae Sphaerococcus. In the last few years, several records of *Codium fragile* have been made in various areas and it has became common on the Algerian coastline (Fig. 10b): in Jijel by Laib & Leghouchi (2012), and by Seridi (2013) in a highly localized zone in Tipasa (Chenoua – Anses de Kouali), in Arzew, Bou Ismail, Ain Benian and Boumerdes (Ould Ahmed, 2015). According to CAR/ASP-PNUE/PAM (2015), this species is also present in El Marsa near Algiers. Hussein (2015) recorded *Codium fragile* in "Pain de Sucre" (Oran-Madrague), in the region of Oran. Recently, it has been observed in the superficial calm subtropical bottoms around Rachgoun Island, where it seems to be highly localized in the creek of the southern sector, where it is common, at 1m depth (PNUE/PAM-CAR/ASP, 2016). The most eastern record of *Codium fragile* was made by Aouissi *et al.* (2013) in Cap de Garde (Annaba), which is 100 km from the Tunisian borders.

Fig. 10a: *Codium fragile* at Habibas islands (-15m depth), (photo credit: 30 September 2015, J.G. Harmelin).

Fig. 10b: Distribution of *Codium fragile, Chondria coerulescens and Griffithsia corallinoides* along the Algerian coast.

The invasive red algae *Melanothamnus harveyi* was misidentified in Algeria as the native *Polysiphonia mottei* by Seridi (1990) in the eastern part of Algiers and by Ould Ahmed (2015) at Habibas islands. The presence of *Polysiphonia atlantica* is suspected in Algeria (Verlaque *et al.*, 2015).

Probably, the first sighting of *Anotrichium furcellatum* under the name of *Griffithsia furcellata*, was made in El Kala by Montagne (1846) (Perret-Boudouresque & Seridi, 1989). Feldmann-Mazoyer & Meslin (1939), based on a sample of Durieu, have recorded this species in Algiers and Feldman & Feldman (1939) have also recorded this species in the mini bay of Aiguades (Bejaia).

Steinheil (1834) reported the presence of *Ulva lactuca* for the first time in Annaba; this was confirmed later by Debray (1897). Debray (1897), according to Montagne (1846), reported the presence of *Ulva lactuca* at several sites located in a wide area, from Oran to Skikda. Many other records of this species have been made in Port of Cherchell (Montagne, 1846); Douaouda (Seurat, 1933); Algiers (Montagne, 1838, based on specimen sampled by Roussel; Montagne, 1846, based on specimen sampled by Bory; Feldmann-Mazoyer, 1941); Tipasa (Seurat, 1927); Bou Ismail (Dieuzeide & Goëau -Brissonnière, 1951); El Marsa (Boudouresque, 1969). *Ulva lactuca* has become common along the Algerian coast; in recent years, it has been observed in several areas, namely, the Bay of Algiers (Seridi *et al.*, 2007); Gulf of Arzew (Bachir Bouiadjra *et al.*, 2010); mini bay of Rabta in Jijel (Laib & Leghouchi, 2012); Annaba (Zitouni, 2015); Bejaia (Saidani *et al.*, 2012); Cherchell, Chenoua, Ain Tagourait, Kouali, Bou Ismail, Sidi Fredj, Ain Benian, Boumerdes, Gouraya, Taza (Ould Ahmed, 2015) (Fig. 11). *Ulva lactuca* is usually observed associated with vermetid terraces (e.g. in Kouali, Dououda, Tipasa). This confirms the observations of Bitar *et al.* (2017) along the Lebanese coast.

Colaconema codicola (Borgesen) H. Stegenga, J.J. Bolton & R.J. Anderson was first recorded in Algiers by Seridi (1990). In Algeria, *Caulerpa chemnitzia* (Esper) J. V. Lamouroux was first reported by Lamouti (personal communication) in Verlaque *et al.* (2015).

Fauna

49 introduced species of fauna have been recorded along the Algerian coast, 56.2% among them are fish, followed by Crustacea (8 Introduced species), Polychaeta (5 Introduced species) and Mollusca (4 Introduced species). Compared to other North African countries, this number is close to the 46 marine alien animal species recorded along the Libyan coastline (Bazairi *et al.*, 2013). Ounifi-Ben Amor *et al.* (2016) have recorded 136 alien species along the Tunisian coast.

Among **molluscs**, *Pinctada imbricata radiata* (Leach, 1814) is found throughout the eastern Mediterranean to the north of Tunisia and Sicily, as well as in Corsica, Toulon (France) and Trieste (Italy) (Gofas & Zenetos, 2003). In Algeria, the first sighting was made on 21 November 2010 in the El Kala region, on the extreme eastern Algerian coast (Refes *et al.*, 2010) (Fig. 12). The first sighting of *Bursatella leachii* was made on 21 November 2010 in the El Kala region (Fig. 12), on the extreme eastern Algerian coast (Refes *et al.*, 2010). In Algerian waters, Lamouti & Bachari in Eleftheriou *et al.* (2011) reported its first sighting between autumn and winter 2008, where ten individuals were observed in Sidi Fredj (Algiers) on soft bottom while in September 2011, two individuals were recorded in the same area; but it is no surprise that the species is present in west Algerian waters because of its establishment along the Mediterranean Moroccan coast (Marchica lagoon) where it is considered as widespread (Selfati *et al.*, 2017).

Several findings of *Mercenaria mercenaria* (Linnaeus, 1758) have been reported by Grimes (2010) at Habibas islands; eight specimens were sampled in 1994, in 25 to 30 m of depth, on coarse sandy bottom. It was also recorded in the Gulf of Arzew in 1996, where nine specimens were sampled from 30 to 83 m of depth. *Mercenaria mercenaria* was recorded in three ports: the port of Annaba in 1996 at 10 m of depth on putrefied muddy bottom, the Port of Arzew (14 specimens) and the Port of Bethioua. In Sidi Fredj (Bahri & Refes, 2017), *Mercenaria mercenaria* was described associated with *Caulerpa cylindracea* from samples taken in December 2010 (in

Fig. 11: Distribution of *Ulva lactuca* along the Algerian coast.

Fig. 12: Distribution of *Pinctada imbricata radiata, Bursatella leachii, Mercenaria mercenaria* and *Taningia danae.*

sandy gravel). Grimes (2010) has also reported the presence of *Mercenaria mercenaria* in the Gulf of Bejaia (3 specimens at 80 m depth and 1 specimen at 91 m depth) on muddy bottom. Quetglas *et al.* (2006) have recorded a specimen of *Taningia danae* captured during a bottom trawl survey at 385-395 m of depth in 2003 between Bench of Alidade & Habibas islands in the Alboran Sea (western Algerian coast).

Three **polychaete** species classified as introduced were recorded by Grimes (2010) from samples collected between 1996 and 1999. *Ficopomatus enigmatica* was recorded from the harbours of Skikda (1997) and Jijel (1999). In summer 1997, *Metasychis gotoi* and *Notomastus aberans* were recorded in the Gulf of Oran. Bakalem (2008) has recorded *Lumbrineris perkinsi* under the name of *Lumbrineris inflata* in Fetzara bay (Golfe of Skikda) from samples dating before 1990 on fine sandy bottom. Çınar (2009) argues that the description and illustrations of *Lumbrineris inflata* by Giangrande *et al.* (1981) fit the characteristics of *Lumbrineris perkinsi* Carrera-Parra (2001). *Lumbrineris inflata* differs from *Lumbrineris perkinsi* mainly in the number of teeth of maxilla III (M III). Although published descriptions and records from the Mediterranean indicate the presence of *Lumbrineris perkinsi*, re-examination of all the material is needed to draw definite conclusions about the identity of the species (Faulwetter *et al.*, 2017).

In their annotated checklist of marine Algerian Crustacean Decapods, Grimes *et al.* (2016) provided an inventory of 114 **decapods** in soft and hard bottom communities from long period sampling surveys (1973-2013). The authors reported four Lessepsian decapods along the Algerian coast and, for the first time, the presence of *Alpheus rapacida* De Man, 1908 (Alpheidae) on soft bottom Algerian benthic communities, in the Bay of Ghazaouet (one individual at 88 m depth in muddy substrate) and in Oran Bay (79-88 m, muddy sand, 4 ind). The non-native species *Pecnon gibbesi* has been reported in Collo (Skikda) in 2010 (Katsanevakis *et al.* 2011) and in the western part of Algiers in the localities of Rais Hamidou and Sidi Fredj by Lamouti & Bachari (2011). The first sighting of *Pecnon gibbesi* in Algerian shallow waters dates back to 2008 in the region of Jijel (DORIS network: http://doris.ffessm.fr/Forum/ReseauDORIS-crabe-plat-Percnon-gibbesi-en-Mediterranee-8359). Grimes *et al.* (2016) also recorded *Alpheus inopinatus* and *Glabropilumnus laevis*. *Eocuma sarsii* was recorded in Arzew Harbour in 1997 by Grimes (2010).

Elasmopus pectenicrus (Bate, 1862) was recorded for the first time along the Algerian coast in 1989 by Bakalem & Dauvin (1992) on fine sandy bottom in the Bay of Algiers (at - 10 m depth). Several specimens of *Penaeus japonicus* Spence Bate, 1888 were reported from the Algerian coast during the Visonde de Eza fish exploration campaign (two specimens are still preserved in ENSSMAL Laboratory) Massuti *et al.* (2004). This species is considered established along the Algerian coast.

The "spaghetti **bryozoan**" *Amathia verticillata* (delle Chiaje, 1822) is considered as one of the more infamous bryozoans due to its massive size and extensive fouling propensities (McCann *et al.*, 2015). *Amathia verticillata* has been recently (2016) recorded in three areas: in shallow and calm waters in small coastal basins, on hard substrates at Rachgoun island (0.5 cm depth) by Alfonso Ramos (PNUE/PAM-CAR/ASP, 2016) and at 1m depth at Paloma and Habibas islands (M. Benabdi, personal communication, 2016, 2017) (Fig. 13a,b). These areas are located at the eastern limit of the Alboran Sea (Cap Figalo-Oran region).

Three Introduced cnidarians have been reported from the Algerian coast. *Clytia linearis* and *Eucheilota paradoxica*, classified as true alien species, and the cryptogenic species *Oculina patagonica*. *Clytia linearis* was recorded for the first time by Picard (1955) in Bou Ismail Bay while *Eucheilota paradoxica* was recorded more recently in Sidi Fredj (West of Algiers) by Kherchouche-Ait Ouadour (2014). The third cnidarian, *Oculina patagonica*, is considered established. The scleractinian *Oculina*

a **b**

Fig. 13: *Amathia verticillata a)* at Rachgoun Island (Alboran Sea) (photo credit: A.A. Ramos Espla, 06/08/2016) and *b)* at Paloma Island (near Alboran Sea) (photo credit. 2016 M. Benabdi).

patagonica was reported for the first time in Algeria in 2007 (Sartoretto *et al.*, 2008) within the framework of the PIM (Mediterranean Small Islands Initiative) at Habibas islands (west of Oran) (Fig. 14a,b,c). The authors reported three colonies of *Oculina patagonica* at Habibas islands, one in 2005 and another two in 2007. The first colony was found on the vertical wall of a small quay. The colony surface was estimated to be about 1900 cm^2, on a sub-horizontal rocky bottom covered by a rich assemblage of photophilic algae. This colony was discovered in 2007, in an environment of photophilic algae and formed a hemispherical mound about 15 cm in height and 20-25 cm in diameter. The Habibas islands are a pristine protected area, but relatively close to two important commercial ports (Oran and Arzew) and are, thus, exposed to larval transport by commercial shipping or to larval flow (Sartoretto *et al.*, 2008).

According to Lamouti *et al.* (2011), *Oculina patagonica* is colonizing diverse areas in the central region of the Algerian coast (Golden Horn, Sidi Fredj and Tamentfoust) (Fig. 15). Lamouti & Bachari (2011) report the presence of *O. patagonica* in Algiers (Aguelli Island, Tamentfoust, and Sidi Fredj). The colonies are large, with the largest widths and lengths varying from 10 to 50 cm, on a rock (natural or riprap) face with encrusting algae "facies" undergoing overgrazing by the sea urchin *Paracentrotus lividus*. *Oculina patagonica* has been observed recently in a polluted area in the port of Oran, at Grand Phare (Taza, Jijel) and Paloma Island near Oran (Benabdi, personal communication, 2016). This zooxanthellate scleractinianencrusting rocky substrata has already been reported from Capo Negro (Galite, Tunisia) (Harmelin *et al.*, 2008). Rebzani Zahaf *et al.* (2013) have reported *Oculina patagonica* from 0.5 to 12m depth at three close areas (Calle Prisonnière, Cap Gros and Cap Segleb), which are located in the extreme east of the Algerian coast, not far from the Tunisian border. In 2015, this species was found at Aguelli Island (CAR/ASP-PNUE/PAM, 2015).

From 1927 to 2017, 30 species of introduced **fishes** have been recorded along the Algerian coast, 15 among them are considered as range-expanding and 2 as vagrant.

The Bluespotted cornetfish *Fistularia commersonii* was recorded in the Gulf of Skikda and the Bay of Bou Ismail, extending from east to west along the Algerian coast (Kara & Oudjane 2009; Hemida & Capapé, 2009; Refes, 2012). According to Azzurro *et al.* (2012), *F. commersonii* is now colonizing the entire Levantine Aegean Sea and the central and western Mediterranean Sea. It has been clearly demonstrated that *Fistularia commersonii* is expanding in parallel along the southern and northern Mediterranean sides (Azzurro *et al.*, 2012).

The Silverstripe blaasop, *Lagocephalus sceleratus* (Tetraodontidae), is recorded all along the Algerian coast. Refes & Semahi (2014), Kara *et al.* (2015) and Babali in Mytilineou *et al.* (2016) have confirmed its

Fig. 15: Distribution of *Oculina patagonica* and year of first record along the Algerian coast.

Fig. 16: Geographical distribution of *Lagocephalus scelaratus* along the Algerian coast (from the first record to the most recent one): 1 (Béni Saf), 2 (Azeffoun), 3 (Stora), 4 (Kristel), 5 (Larhat), 6 (Arzew), 7 (Béjaïa), 8 (Zemmouri), 9 (La Marsa), 10 (El Kala), 11 (Annaba), 13 (Bordj El Bahri), 14 (Malous), 15 (Ténès), 16 (El Hilel).

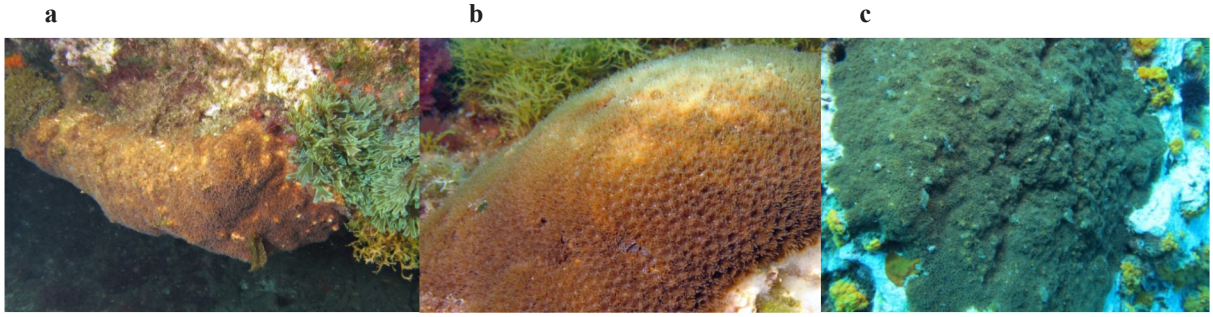


Fig. 14: *Oculina patagonica* at Habibas Islands: a) Quay of Port (photo credit: J.G. Harmelin), b) "Baie de la Morte" (photo credit: J.G. Harmelin), c) Paloma island (photo credit: M. Benabdi).

presence at several localities along the Algerian coast (Fig. 16, Table 4).

In February 2017, Kassar & Hemida *in* Stamouli *et al.* (2017) recorded the round herring *Etrumeus golanii*, for the first time, in Western Mediterranean waters along the Algerian coast (Fig. 17).

The African threadfin deer (*Galeoides decadactylus*) has been reported from the Gulf of Oran (Dieuzeide, 1927) and from Bou Ismail Bay (Dieuzeide *et al.*, 1955). The Prickly puffer (*Ephippion guttifer*) was reported for the first time in the area of Ténès (Dieuzeide, 1933) (Fig. 18 a, b); subsequently it is found in the Gulf of Annaba (Derbal & Kara, 2001). In 2014, another specimen of *Ephippion guttifer* was sampled by CNRDPA and identified by Refes (personal communication) (Fig. 18 c).

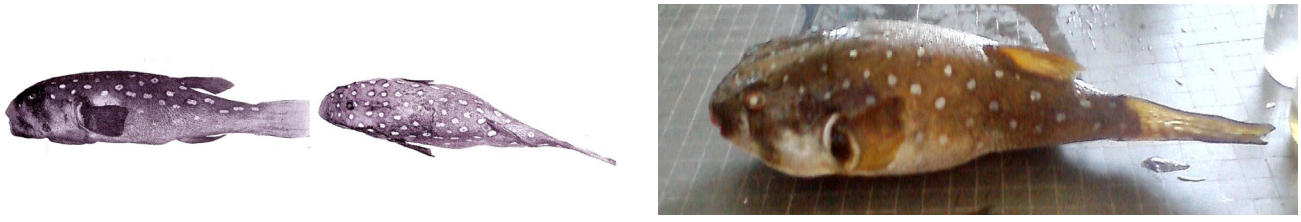
The ocellate wedge sole, *Dicologlossa hexophthalma*, has been reported from two localities: Gulf of Arzew and Bay of Bou Ismail (Massuti *et al.*, 2004).

Hyperoglyphe perciformis (Mitchill, 1818) seems to be wandering in the Eastern Atlantic; juveniles occasionally accompanying floating objects have been sighted across the Atlantic, around the British Isles, off Portugal,

Table 4. Records of *Lagocephalus sceleratus* along the Algerian coast.

Sector	Locality	Coordinates	Date of record	Length (mm)	Weight (gr)	Authors
West	Malous	35.244207°/-1.580405°	27/10/2014	530	2000	Babali in Mytilineou *et al.,* 2016
	Béni Saf	35.337830°/-1.409805°	14/02/2012	647	2758	Refes & Semahi, 2014
	El Hilel-Oued Halouf	35.366730°/-1.275879°	09/03/2016	470	1150	Babali in Mytilineou *et al.,* 2016
	Kristel	35.824847°/-0.503057°	27/05/2012	562	2351	Refes & Semahi, 2014
	Arzew	35.854501°/-0.284010°	19/11/2012	514	1425	Refes & Semahi, 2014
	Ténès	36.536226°/1.306068°	13/10/2015	-	2000	Babali in Mytilineou *et al.,* 2016
Center	Larhat	36.575259°/1.800279°	14/07/2012	512	1428	Refes & Semahi, 2014
	Bordj El Bahri	36.786117°/3.219557°	06/07/2014	582	2590	Babali in Mytilineou *et al.,* 2016
	Zemmouri	36.817840°/3.564937°	14/06/2013	521	1198	Refes & Semahi, 2014
	Azeffoun	36.914405°/4.410933°	21/02/2012	568	1872	Refes & Semahi, 2014
East	Béjaïa	36.782887°/5.093545°	17/03/2013	589	2001	Refes & Semahi, 2014
	Stora	36.908229°/6.893586°	18/03/2012	641	2612	Refes & Semahi, 2014
	La Marsa	36.823811°/3.246890°	07/08/2013	501	1205	Refes & Semahi, 2014
	Annaba	36.903729°/7.796854°	11/01/2014	480	1400	Kara *et al.,* 2015
	El Kala	36.917050°/8.439353°	14/12/2013	-	-	Kara *et al.,* 2015

Fig. 17: *Etrumeus golanii* DiBattista, Randall & Bowen, 2012 of Cherchell, Algeria (photo credit: A. Kassar).



a **b** **c**

Fig. 18: (a) & (b), Specimen of *Ephippion guttifer* sampled and described in Ténès by Dieuzeide (1933); (c) Specimen of *Ephippion guttifer* sampled by CNRDPA (photo credit: W. Refes).

to the Azores and further north to Iceland (Karrer, 1986). A specimen from Marseille (France), cited by Moreau (1881), is the first record of *H. percifomis* in the Mediterranean Sea (Karrer, 1986). A new specimen of this species was observed in Algeria in 2015 (Surcouf in Algiers) (M. Benabdi, personal communication, 2015) (Fig. 19).

The Montavia doctofish, *Acanthurus monroviae*, was reported from Bou Ismail Bay (Hemida *et al.*, 2004a) (Fig. 20) and the Gulf of Annaba (Hemida *et al.*, 2004b). In 2002, Hemida (personal communication) recorded one specimen of *Acanthurus monroviae* measuring 38 cm in length, captured by a fisherman in Ain Benian (west of Algiers).

Two chondrichthyans, considered as vagrant species, have been observed in Algerian waters: the bignose shark *Carcharhinus altimus* and the sickle shark *Carcharhinus falciformis* (Hemida & Labidi, 2001). *Carcharhinus altimus* was observed as a by-catch in the various tuna fisheries of Ghazaouet, Oran, Annaba, and in the waters between Tenès and Azeffoun (Hemida *et al.*, 2002).

It was very difficult to establish an inventory and distribution of introduced species along the Algerian coast due to the lack of taxonomists and biomonitoring systems, as well as gaps in available data. The most studied groups along the Algerian coast are macroalgae and fishes, which are documented in terms of description, location and in some cases spacial coverage. On the other hand, these two groups, for several and diverse reasons, have presented an interest for international scientific collaboration, particularly in the southwestern Mediterranean sub-region and as such have motivated scientific investigations and studies. These considerations are inferred from the results of this first national assessment of Algerian Introduced species. Future investigations on other groups, such as Ascidiacea, Bryozoa, Echinodermata, Cnidaria, Anthozoa, Turbellaria, Sipuncula and other pelagic taxa (zooplankton and phytoplankton), as well as deeper research on macroalgae and fish will certainly increase the knowledge and possibly extend the list of Algerian Introduced species. On comparing studies on introduced species with other marine zones of the southwester n Mediterranean Sea, this assessment shows that the issue is very well-known and documented in Tunisia and least documented in Morocco, whereas increasing scientific interest and work is in progress in Algeria and Libya.

Fig. 19: A specimen of *Hyperoglyphe perciformis* from Algeria in 2015 (photo credit: M. Benabdi).

Fig. 20: *Acanthurus monroviae* (photo credit: 2004, F. Hemida).

Conclusions

This review of recorded marine introduced species along the Algerian coast clearly reveals a gap in knowledge as regards Introduced species. This is directly and mainly linked to limited scientific interest and the lack of taxonomists for certain groups. However, many data on introduced species have not been exploited yet. This paper attempted to trace some of these data, in order to compile them and check, as far as possible, the validity of these records. Nevertheless, further efforts are required to find all the literature on Introduced species that has not been exploited (open to the wider scientific community) to date. Many such works, which are classified as "grey literature", provide very important information on the presence and in some cases on the distribution and mapping of Introduced species along the Algerian coast.

The present work was carried out mainly within the framework of international cooperation and partnership programs, while further projects need to be carried out. The absence of an information system on marine biodiversity in general, and on Introduced species in particular, does not facilitate the centralization of data and their validation through scientific procedures established and agreed upon by the scientific community involved in marine biodiversity. This makes the data fragmentary, disparate and dispersed. This situation does not simplify the monitoring of the occurrence and expansion of these species. The establishment of a geographic information

system, dedicated to marine biodiversity with an Introduced species component, is essential for the continuity of scientific research on Introduced species. It should also be pointed out that the majority of older works do not specify the geo-location of species, and sometimes do not specify the environmental conditions of the sightings. This information is indispensable for monitoring and assessing, in particular, the potential impacts of Introduced species on ecosystems and ecosystem services, in the areas where they appear and settle. Therefore, considering objectively the increasing interest of young researchers over the last years, we expect an enlargement of the Introduced species list in the near future. Since many first records of Introduced species along the Algerian coast are not recent, further work is needed including field studies in order to confirm and assess the range of their spatial expansion. The geographical position of the Algerian basin, relatively far from the Suez Canal and close to the Strait of Gibraltar, makes this location an area of special importance. There is an absolute lack of knowledge about the effects of Lessepsian species on the coralligenous and maërl communities of the western Mediterranean. The analysis carried out within the framework of this first national assessment of Introduced species in Algeria highlights the following elements:

i. Significant gaps in the pathways and conditions for the establishment of Introduced species in Algeria. Nevertheless, at regional level, in the last decade, our knowledge on alien species in the Mediterranean, their pathways and gateways of introduction, their spatial distribution, and their impacts have improved substantially through many basin-wide, national, and local studies, several scientific works and assessment. But it is still necessary to improve our knowledge in order to downscale this phenomenon. According to UNEP (2012), the North African ports of Algeria, Tunisia, Libya and those of Egypt, from which the oil from the Persian Gulf is shipped, account for more than 90% of the total crude oil loaded in the Mediterranean. It is estimated that 69% of the volume of ballast water received by Mediterranean ports concerns three countries: Algeria, Egypt and Libya, which have large oil terminals and where the oil tankers arrive with empty ballast tanks in order to take delivery of oil. This will increase the risks of bioinvasions in the future.
ii. The level of knowledge and geographical distribution of this knowledge is proportional to the observation and monitoring effort and this is why nearly half the data concern the central sector, followed by the western sector.
iii. The resilience of Island areas, located within or close to the Alboran Sea, such as Habibas, Rachgoun and Paloma Islands has been demonstrated. Less than 5 Introduced species are identified in these areas without signs of invasions or negative impact in the light of the current knowledge.
iv. Regarding the current level of knowledge on Algerian Introduced species, we are unable to give a status to all alien species reported along the Algerian coast. Moreover, the lack of data centralization, in the form of databases or national geographic information system, is considered as a main obstacle for the visibility of available data, groups and areas that need more exploration and studies. To enhance the knowledge on Introduced species in this part of the Mediterranean Sea, it is crucial to improve and reinforce national capacities related to taxonomy. In addition, more sub-regional (Morocco, Algeria, Tunisia, Libya and Egypt) and regional scientific collaboration will be necessary to understand the pathways and gateways of species introductions, their spatial distribution and their impacts on native species and local ecosystems. An assessment of Western Mediterranean Introduced species (Morocco, Spain, Algeria, France, Tunisia, and Italy) may certainly help to understand more sub-regional aspects of introduced species.

Acknowledgements

The authors are grateful to the reviewer and would like to thank Argyro Zenetos for her helpful suggestions and comments on an earlier version of the manuscript. A word of gratitude is dedicated to Fabrice Bernard (French Conservatory of Coasts), Jean Georges Harmelin (University of Marseille), Alfonso Angel Ramos Espla (Center of Marine Investigation Marina de Santa Pola, University of Alicante, Spain), Farid Hemida and Abderahman Kassar (National School of Marine Sciences and Coastal Management) and Nadji Kouaci for their precious contribution of photographs and original data. Bahri (PhD Student-ENSSMAL) has kindly accepted to share her unpublished data with us, and Zeineb Khan's (Zoobenthos engineer-ENSSMAL) support in checking the available sightings of Algerian introduced species is highly appreciated. The data presented in this paper were partially supported by research projects carried out by the National School of Marine Sciences and Coastal Management (ENSSMAL), collaboration between the Ministry of Environment and Renewable Energies Algeria and the RAC/SPA-Regional Activity Centre for Specially Protected Areas (Reghaia and Rachgoun Island), and results of the PIM initiative explorations. The authors would like to address special thanks to the Marine Ecological Association of Barbarous (Oran) who supported the scientific explorations at Rachgoun and Paloma islands.

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