

Mediterranean Marine Science

Vol 17, No 1 (2016)

VOL 17, No 1 (2016)



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doi: [10.12681/mms.1371](https://doi.org/10.12681/mms.1371)

To cite this article:

OUNIFI- BEN AMOR, K., RIFI M., GHANEM, R., DRAEIF, I., ZAOUALI, J., & BEN SOUISSI, J. (2015). Update of alien fauna and new records from Tunisian marine waters. *Mediterranean Marine Science*, 17(1), 124–143. <https://doi.org/10.12681/mms.1371>

Update of alien fauna and new records from Tunisian marine waters

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Handling Editor: Argyro Zenetos

Received: 26 May 2015; Accepted: 12 October 2015; Published on line: 8 February 2016

Abstract

An updated inventory of alien marine fauna in coastal and offshore Tunisian waters is presented. Records were compiled from scientific and 'grey' publications, presentations at scientific meetings, theses presented in fulfillment of requirements towards MSc and PhD degrees, websites and personal observations. 136 alien species were recorded in Tunisian waters, 60 records in northern coasts, west Mediterranean and 76 in central and southern coasts, central Mediterranean. Nearly half of the first sightings in Tunisian waters took place in the Gulf of Gabès. The dominant taxa are Crustacea (24%), Mollusca (23%), fishes (19%) and Annelida (13%). Twenty-one species previously reported as aliens were, upon consideration, reclassified as range-expanding Atlantic species. *Amathia verticillata*, previously considered native to the Mediterranean, is reclassified as pseudoindigenous. Twenty-one alien species are newly recorded from Tunisia, including five fish species, five polychaetes, four crustaceans, four molluscs, and one each schyphozoan, bryozoan and tunicate. The findings of *Gibberulus gibberulus albus*, *Morula aspera* and *Calcinus latens*, three species new to the Mediterranean, and of *Actaeodes tomentosus*, reported for the second time in the basin, are described. Species were classified according to their establishment status and their origins. This contribution highlights the dual origin of biological invasion in Tunisian waters (Red Sea and Atlantic), with slightly more species of Red Sea and Indo-Pacific origins (61.76%). The impact of the alien species in Tunisian waters was discussed.

Keywords: Biodiversity, alien species, IAS impact, expanding range, Tunisia, Gulf of Gabès, Mediterranean Sea.

Introduction

The number of alien species recorded in the Mediterranean Sea has been increasing: Zenetos *et al.* (2008) cited a rate of one new record every nine days. Marine biological invasions are considered a major threat to the biodiversity of the Mediterranean Sea (Pancucci *et al.*, 2005; Zenetos *et al.*, 2005; Katsanevakis *et al.*, 2009; Çinar *et al.*, 2011; Zenetos *et al.*, 2012; Bazairi *et al.*, 2013; Evans *et al.*, 2015), affecting habitats and ecosystem function (Breithaupt, 2003). The Mediterranean Sea is under multiple stressors due to anthropogenic activities such as pollution, overfishing, intensification of maritime traffic, aquaculture and global warming (Bax *et al.*, 2003; Garrabou *et al.*, 2003; Streftaris *et al.*, 2005; Occhipinti-Ambrogi, 2007; Perez, 2008; Galil, 2009; 2011). In addition, some invasive species impact human health (Öztürk & İşinibilir, 2010; Ben Souissi *et al.*, 2014a) and economical activities such as fisheries, aquaculture and tourism (Streftaris & Zenetos, 2006).

Por (1978) pointed out that the presence of aliens is underestimated in the Mediterranean Sea. Indeed, only well-known taxonomic groups received attention while other small groups and less obvious ones are overlooked. Following the last inventory of Mediterranean alien spe-

cies (Zenetos *et al.*, 2010) and new added records (Zenetos *et al.*, 2012; Siokou *et al.*, 2013; Bilecenoglu *et al.*, 2013) more than 1000 alien species are listed. However, Galil *et al.* (2014), inventoried a lower number of validated alien species in the Mediterranean.

Tunisia is located between two areas, the western Mediterranean (WMED) and the central Mediterranean (CMED). The WMED comprises north Tunisia, the area between the Algerian border and the Cape Bon Peninsula (Kélibia), and the central part CMED extends from Kélibia to the Libyan border, including the Gulf of Gabès. Tunisia is a transitional zone between the two basins, under the influence of the Sicily strait, and therefore a key area for understanding the influx of alien species in the whole Mediterranean Sea (Guidetti *et al.*, 2010; Azzurro *et al.*, 2014a). At present, data regarding alien species are scarce and fragmentary, with separate accounts for some taxa: molluscs (Antit *et al.*, 2011), fishes (Bradai *et al.*, 2004 a,b), annelids of the Cape Bon Peninsula (Zaabi *et al.*, 2012), bryozoans (D'Hondt & Mascarell, 2004; D'Hondt & Ben Ismail, 2008), ascidians (Lakhrach *et al.*, 2012) and amphipods (Zakhama-Sraeib *et al.*, 2009). Some of these studies do not specifically target aliens. At a Mediterranean level, records of Tunisian alien species were reported by Zibrowius (1992) Zenetos *et al.* (2005;

2010) and Galil (2009). In this contribution, the up-to-date (March 2015) alien fauna records from Tunisian marine and estuarine waters have been examined and their list is reported.

Material and Methods

Study area

The Tunisian coastline is 2290 km long including islands and is subdivided in three sub-regions, north, central and south (Gulf of Gabès) (Fig. 1). Northern Tunisia, with its narrow shelf and extensive rocky substrates, is part of the western basin of the Mediterranean Sea and is under the influence of the Atlantic currents. Central and southern Tunisia are part of the central Mediterranean and are characterized by a wide shelf, especially in the very shallow Gulf of Gabès (Bradai *et al.*, 2004b).

Data collection

Records of marine and estuarine alien fauna were based on a compilation of published articles, articles in press, grey literature and unpublished data, including surveys and awareness campaigns carried out in the last two decades. The data covers the littoral zone including islands, lagoons and harbors from the Algerian border to

the Libyan frontier, with a particular interest to the Gulf of Gabès. Surveys were conducted from 0 to 50 m depth using experimental and professional gear, scuba diving and also citizen science (Azzurro *et al.*, 2014a).

Nomenclature and terminology

The nomenclature adopted in this paper follows the World Register of Marine Species (WoRMS). The establishment status of each species was assessed and given according to the terminology, as proposed in Zenetos *et al.* (2010).

Results and Discussion

Update of records of alien fauna and range-expanding species

Records of alien fauna

Until March 2015, a total of 136 alien species have been reported in Tunisian waters among which are 34 crustaceans, 31 mollusks, 26 fishes, 18 annelids and 27 species from other taxa (Fig. 2 and Table 1). From these species, 62 % are Established, 30 % are Casual, 4% are Questionable and 4% Cryptogenic. Most of these species (61.76%) are of Indo-Pacific or Indian Ocean origin.

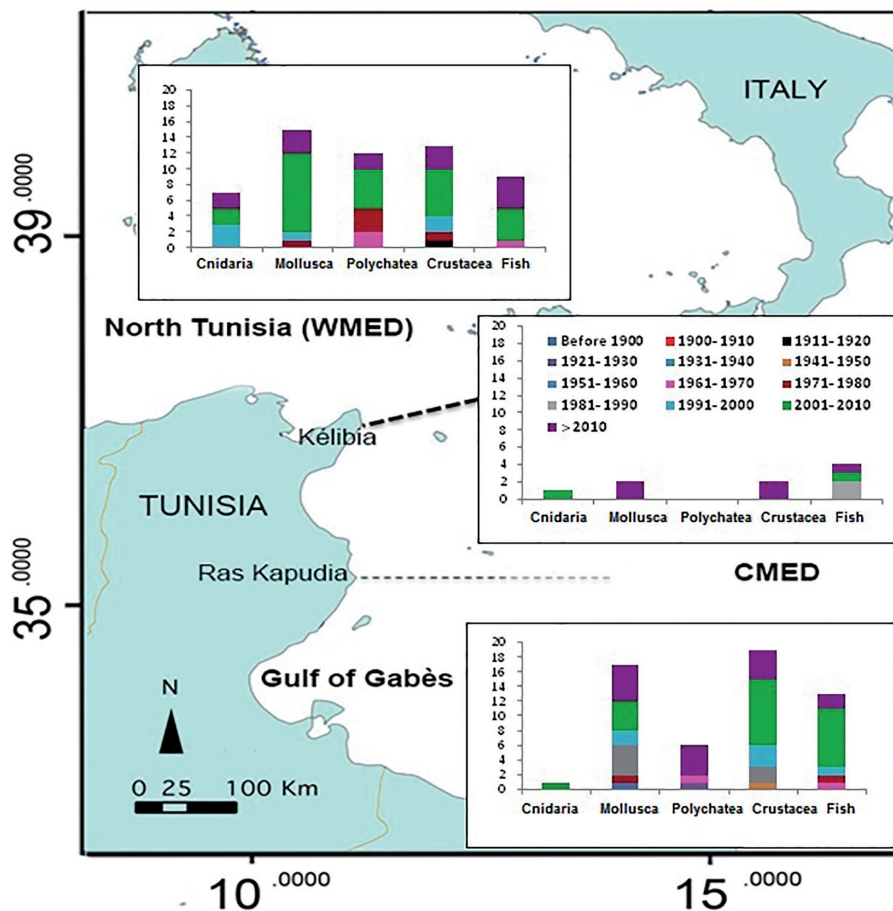


Fig. 1: Number of first sighting marine alien fauna per major groups along the Tunisian coasts according to the MSFD subdivisions (WMED: northern Tunisia and CMED: central Tunisia and Gulf of Gabès).

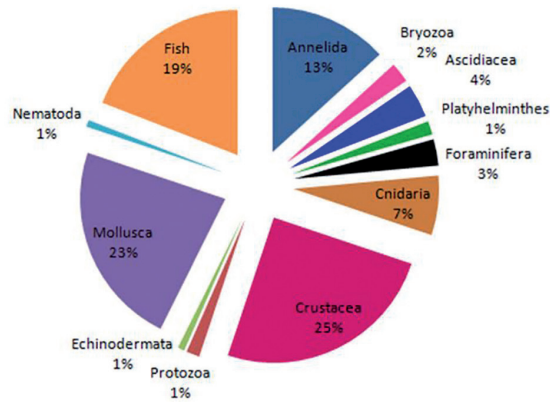


Fig. 2: Percentage of alien marine fauna in Tunisian waters per taxonomic group.

Twenty-one new records are added to the list of alien fauna of Tunisia including three records new for the Mediterranean Sea: two gastropod species, *Gibberulus gibberulus albus* and *Morula aspera*, and the hermit crab *Calcinus latens*. In addition, a second occurrence of the Lessepsian crab *Actaeodes tomentosus* was observed.

First and second records in the Mediterranean Sea

Gibberulus gibberulus albus (Mörch, 1850) (Fig. 4A)

One specimen of the endemic Red Sea gastropod *G. gibberulus albus* was collected for the first time in the Mediterranean Sea by a fisherman, in the Gulf Gabès (La Chebba). This specimen can be described as follows; the shell is conical and very sharp, spire with many thickened white varices. It presents short axial smooth ribs. External

Table 1. Marine alien species recorded up March 2015 with the First sighting in Tunisian waters (WMED or CMED). Invasive species in Tunisia are marked by *and grey shaded confirms the absence of the species in the area.

Species	Authority, Year	Origin	1 st Tunisian sightings		Establishment Success
			1 st WMED sighting	1 st CMED sighting	
Protozoa					
<i>Marteilia refringens</i>	Grizel, Comps, Bonami, Cousserans, Duthoit & Le Pennec, 1974	Unknown	?	2009 Elgharsalli <i>et al.</i> , 2013	Established
<i>Perkinsus olsenii</i>	R.J.G.Lester & G.H.G.Davis, 1981	Cosmopolitan	2004-2006 Attia El Hili <i>et al.</i> , 2007	?	Established
Chromista: Foraminifera					
<i>Amphistegina lobifera</i>	Larsen	Indo-Pacific	2012 Langer <i>et al.</i> , 2012	1962 Glacon, 1962	Cryptogenic
<i>Coscinospira hemprichii</i>	Ehrenberg, 1839	Indo-Pacific	?	2008 Langer, 2008	Cryptogenic
<i>Pseudolachlanella slitella</i>	Langer	Indo-Pacific	?	1979 Blanc-Vernet <i>et al.</i> , 1979	Established
<i>Sorites variabilis</i>	Lacroix, 1941	Indo-Pacific	?	1962 Glacon, 1962	Established
Animalia: Cnidaria					
Hydrozoa					
<i>Coryne eximia</i>	Allman, 1859	Circum (sub) tropical	2004-2005 Touzri <i>et al.</i> , 2012	2004 Touzri <i>et al.</i> , 2004	Casual
<i>Euheilota paradoxica</i>	Mayer, 1900	Circumtropical	1993-1995 Daly-Yahia <i>et al.</i> , 2003	?	Casual
<i>Fabienna oligonema</i>	(Kramp, 1955)	Atlantic Ocean	1995 Daly-Yahia <i>et al.</i> , 2003		Casual
<i>Halicsera bigelovi</i>	Kramp, 1947	Atlantic Ocean	2001 Touzri <i>et al.</i> , 2012		Established
Scyphozoa					
<i>Phyllorhiza punctata</i>	Lendenfeld, 1884	Circumtropical	2012 Gueroun <i>et al.</i> , 2014	?	Established
<i>Rhopilema nomadica</i>	Galil, 1990	Red Sea	2010 Daly-Yahia <i>et al.</i> , 2013	2008 Daly-Yahia <i>et al.</i> , 2013	Established
<i>Stomolophus meleagris</i>	Agassiz, 1862	Atlantic/ Pacific	1995 Daly-Yahia <i>et al.</i> , 2003	?	Casual
Anthozoa					
<i>Oculina patagonica</i>	de Angelis, 1908	South West Atlantic	2006 Sartoretto <i>et al.</i> , 2008		Established
Animalia: Platyhelminthes					
<i>Tetrancistrum polymorphum</i>	(Paperna, 1972) Kritsky, Galli & Yang, 2007	Red Sea	?	1974 Ktari & Ktari, 1974	Casual
<i>Tetrancistrum suezicum</i>	(Paperna, 1972) Kritsky, Galli & Yang, 2007	Red Sea	?	1974 Ktari & Ktari, 1974	Casual
Animalia: Mollusca					
Polyplacophora					
<i>Acanthopleura gemmata</i>	(Blainville, 1825)	Indo-Pacific/ Red Sea	?	2012 Zaouali <i>et al.</i> , 2013a	Casual
Bivalvia					

(continued)

Table 1 (continued)

Species	Authority, Year	Origin	1 st Tunisian sightings 1 st WMED sighting	1 st CMED sighting	Establishment Success
<i>Anadara transversa</i>	(Say, 1822)	West Atlantic	2010 Antit <i>et al.</i> , 2011	?	Casual
<i>Arcuatula senhousia</i>	(Benson in Cantor, 1842)	Temperate North Pacific	2004 Ben Souissi <i>et al.</i> , 2005a	?	Established
<i>Crassostrea gigas</i>	(Thunberg, 1793)	North West Pacific	1972 Medhioub & Zaouali, 1988		Established
<i>Fulvia fragilis</i> *	(Forsskål in Niebuhr, 1775)	Indian Ocean	2001 Ben Souissi <i>et al.</i> , 2003	1994 Passamonti, 1996	Established
<i>Pinctada imbricata radiata</i> *	(Leach, 1814)	Indo-Pacific/ Red Sea	2008 Diawara <i>et al.</i> , 2008	1892 Dautzenberg, 1895	Established
<i>Saccostrea cucullata</i>	(Born, 1778)	Indo-Pacific	2002 Romdhane & Tritar, 2002	?	Questionable
<i>Ruditapes philippinarum</i> *	(A. Adams & Reeve, 1850)	Temperate North Pacific	1996 Ben Souissi <i>et al.</i> , 2005a	2005 Zamouri-Langar <i>et al.</i> , 2006	Established
Gastropoda					
<i>Aeteocina mucronata</i>	(Philippi, 1849)	Red Sea	?	1989 Hoenselaar & Gulden, 1991	Questionable
<i>Alvania dorbigny</i>	(Audouin, 1826)	Cosmopolitan	2007 Campani, 2008	?	Cryptogenic
<i>Bursatella leachii</i> *	Blainville, 1817	Circumtropical	2001 Ben Souissi <i>et al.</i> , 2003	1982 Enzenross & Enzenross, 2001	Established
<i>Cellana rota</i>	(Gmelin, 1791)	Indian Ocean/Red Sea		2007 Zaouali <i>et al.</i> , 2007b	Established
<i>Cerithium scabridum</i> *	Philippi, 1848	Indian Ocean/Red Sea	2009-2010 Antit <i>et al.</i> , 2011	1997 Enzenross & Enzenross, 2001	Established
<i>Chromodoris quadricolor</i>	(Rüppell & Leuckart, 1830)	Red Sea		2003 Ben Souissi <i>et al.</i> , 2004a	Casual
<i>Crepidula fornicata</i>	(Linnaeus, 1758)	North West Atlantic		1984 Fehri-Bedoui, 1986	Questionable
<i>Diodora ruppellii</i>	(G. B. Sowerby I, 1835)	Indo-Pacific/ Red Sea	2003 Zaouali, unpublished data		Casual
<i>Erosaria turdus</i>	(Lamarck, 1810)	Indian/ Red Sea		2003 Wimart-Rouseau, 2004	Established
<i>Favorinus ghanensis</i>	Edmunds, 1968	Tropical Atlantic	2003 Ben Souissi <i>et al.</i> , 2004a		Casual
<i>Melibe viridis</i>	(Kelaart, 1858)	Indo-Pacific		1982 Cattaneo Vietti <i>et al.</i> , 1990	Established
<i>Mitrella psilla</i>	(Duclos, 1846)	Atlantic Ocean	2008 Antit <i>et al.</i> , 2010		Established
<i>Monetaria annulus</i>	(Linnaeus, 1758)	Indo-Pacific		2006 Ben Souissi & Zaouali, 2007	Casual
<i>Nerita sanguinolenta</i>	Menke, 1829	Indo-Pacific / Red Sea		2012 Zaouali <i>et al.</i> , 2013a	Casual
<i>Polycerella emertoni</i>	A. E. Verrill, 1880	Pantropical	2009 Antit <i>et al.</i> , 2011		Established
<i>Tayuva lilacina</i>	(Gould, 1852)	Indo-Pacific/ Red Sea	2003 Ben Souissi <i>et al.</i> , 2005a		Casual
<i>Tornus jullieni</i>	Adam & Knudsen, 1969	West Africa		1973 Piani & Brini, 1984	Questionable
Cephalopoda					
<i>Sepioteuthis lessoniana</i>	Lesson, 1830	Indo-Pacific	?	2011 Eleftheriou <i>et al.</i> , 2011	Casual
<i>Tremoctopus gracilis</i>	(Eydox & Souleyet, 1852)	Indo-Pacific	2011 Rifi & Ben Souissi, 2014		Casual
Animalia: Polychaeta					
<i>Diopatra hupferiana monroi</i>	(Day, 1957)	Indian	1975 Cantone <i>et al.</i> , 1978	?	Casual
<i>Eunice floridana</i>	(Pourtalès, 1867)	West Atlantic	2003 Ayari & Afi, 2003	?	Casual
<i>Eunice tubifex</i>	Crossland, 1904	Indian	2006 Zaabi <i>et al.</i> , 2012		Established
<i>Ficopomatus enigmaticus</i> *	(Fauvel, 1923)	Subtropical	1944 Heldt, 1953	1927 Seurat, 1927	Established
<i>Hydroïdes dianthus</i> *	(Verrill, 1873)	North West Atlantic	1965 Vuillemin, 1965	?	Established
<i>Hydroïdes dirampha</i> *	Mörch, 1863	Circumtropical	1978 Zibrowius, 1978	?	Established
<i>Hydroïdes elegans</i> *	(Haswell, 1883)	Circumtropical	1965 Vuillemin, 1965	?	Established
<i>Hyboscolex longiseta</i>	Schmarda, 1861	Cosmopolitan	1975 Cantone <i>et al.</i> , 1978	?	Questionable

(continued)

Table 1 (continued)

Species	Authority, Year	Origin	1 st Tunisian sightings		Establishment Success
			1 st WMED sighting	1 st CMED sighting	
<i>Isolda pulchella</i>	Müller in Grube, 1858	Circumtropical	2005-2006 Zaabi <i>et al.</i> , 2009	?	Casual
<i>Metasychis gotoi</i>	(Izuka, 1902)	Indo-Pacific	2005-2006 Zaabi <i>et al.</i> , 2009	?	Established
<i>Naineris setosa</i>	(Verrill, 1900)	Subtropical- tropical American	?	2012-2013 Khedhri <i>et al.</i> , 2014	Established
<i>Notomastus aberans</i>	Day, 1957	Indian/ Red Sea	?	1965 De Gaillande, 1970	Established
<i>Pista unibranchia</i>	Day, 1963	Indo-Pacific	2006 Zaabi <i>et al.</i> , 2012	?	Established
Animalia: Nematoda					
<i>Anguillicoloides crassus</i>	(Kuwahara, Niimi & Itagaki, 1974)	Asia	2006 Ben Abdallah Gargouri & Maamouri, 2006		Established
Animalia: Crustacea					
Cirripedia					
<i>Amphibalanus eburneus</i>	(Gould, 1841)	West Atlantic	1998 Southward <i>et al.</i> , 1998	2009 El Lakhrah <i>et al.</i> , 2012	Established
Copepoda					
<i>Paracartia grani</i>	Sars G.O., 1904	Atlantic	1993 Daly-Yahia <i>et al.</i> , 2004		Established
Amphipoda					
<i>Caprella scaura</i>	Templeton, 1836	Indian		2007-2008 Ben Souissi <i>et al.</i> , 2010	Established
<i>Cymadusa filosa</i>	Savigny, 1816	Info-pacific	1911 Chevreux, 1911	1911 Chevreux, 1911	Cryptogenic
<i>Elasmopus pecteniscrus</i>	(Bate, 1862)	Circumtropical		2006- 2008 Zakhama-Sraieb <i>et al.</i> , 2009	Established
<i>Hamimaera hamigera</i>	(Haswell, 1879)	Circumtropical		2010 Ben Souissi <i>et al.</i> , 2010	Casual
<i>Gammaropsis togoensis</i>	(Schellenberg, 1925)	Cosmopolitan		2007 Kahri <i>et al.</i> , 2010	Established
<i>Stenothoe gallensis</i>	Walker, 1904	Circumtropical		2006-2008 Zakhama-Sraieb <i>et al.</i> , 2009	Established
Isopoda					
<i>Anilocra pilchardi</i>	Bariche & Trilles, 2006	Info-Pacific		2010 Ben Souissi <i>et al.</i> , 2010	Casual
<i>Paracerceis sculpta</i>	(Holmes, 1904)	Subtropical	1978 Rezig, 1978		Established
<i>Paradella diana</i>	(Menzies, 1962)	North East Pacific	2001 Bey <i>et al.</i> , 2001		Established
<i>Sphaeroma walkeri</i>	Stebbing, 1905	Indian	2002 Ben Souissi <i>et al.</i> , 2003		Established
Decapoda					
<i>Alpheus inopinatus</i>	Holthuis & Gottlieb, 1958	Indian/Red Sea		1950 Forest & Guinot, 1956	Casual
<i>Elamena mathoei</i>	(Desmarest, 1823)	Indian	2011 Zaouali <i>et al.</i> , 2013b		Casual
<i>Eucrate crenata</i>	(De Haan, 1835)	Indo-Pacific	2001 Ounifi Ben Amor <i>et al.</i> , 2006	1985 Zaouali, 1993	Established
<i>Grapsus granulatus</i>	H. Milne Edwards, 1853	Red Sea		2006 Zaouali <i>et al.</i> , 2007a	Casual
<i>Hemigrapsus sanguineus</i>	(De Haan, 1835)	Pacific Ocean	2003 Ben Soussi <i>et al.</i> , 2004a		Casual
<i>Libinia dubia</i> *	H. Milne Edwards, 1834	West Atlantic		1996 Enzenross & Enzenross, 2001	Established
<i>Menaethius monoceros</i>	(Latreille, 1825)	Indo-Pacific	2011 Zaouali <i>et al.</i> , 2013 in Siokou <i>et al.</i> , 2013		Casual
<i>Necora puber</i>	(Linnaeus, 1767)	North West Atlantic		2004 Saidi <i>et al.</i> , 2009	Established
<i>Percnon gibbesi</i> *	(H. Milne Edwards, 1853)	West Atlantic	2004 MedMPA, 2004	2010 Sghaier <i>et al.</i> , 2011	Established
<i>Pilumnopoeis vauquelini</i>	(Audouin, 1826)	Indian/Red Sea	2002 Ben Souissi <i>et al.</i> , 2003	?	Established
<i>Plagusia squamosa</i>	(Herbst, 1790)	Indo West Pacific		2006 Zaouali <i>et al.</i> , 2007b	Established
<i>Portunus (Portunus) segnis</i> *	(Forskål, 1775)	Indian		2014 Rifi <i>et al.</i> , 2014	Established
<i>Rhithropanopeus harrisi</i>	(Gould, 1841)	North Atlantic	2003 Ben Soussi <i>et al.</i> , 2004a		Established
<i>Metapenaeus monoceros</i> *	(Fabricius, 1798)	Indo West Pacific		1993 Missaoui & Zaouali, 1995	Established

(continued)

Table 1 (continued)

Species	Authority, Year	Origin	1 st Tunisian sightings		Establishment Success
			1 st WMED sighting	1 st CMED sighting	
<i>Metapenaeus stebbingi</i>	Nobili, 1904	Indian		1996 Ben Hadj Hamida-Ben Abdallah <i>et al.</i> , 2006	Established
<i>Rimapenaeus similis</i>	(Smith, 1885)	West Atlantic		2006 Ben Hadj Hamida- Ben Abdallah <i>et al.</i> , 2010	Established
<i>Trachysalambria curvirostris</i> *	(Stimpson, 1860)	Red Sea		1990 Zaouali, 1993	Established
Stomatopoda					
<i>Erugosquilla massavensis</i>	(Kossmann, 1880)	Indian/Red Sea	2014 Ounifi Ben Amor <i>et al.</i> , 2015	2013 Ounifi Ben Amor <i>et al.</i> , 2015	Established
Animalia: Bryozoa					
<i>Tricellaria inopinata</i>	d'Hondt & Occhipinti Ambrogi, 1985	Indo-Pacific	2005 Ben Souissi <i>et al.</i> , 2006a		Established
<i>Amathia verticilla</i> *	(delle Chiaje, 1822)	Atlantic		1934 Seurat, 1934	Pseudoindigenous/ Cryptogenic
Animalia: Echinodermata					
<i>Ophiactis savignyi</i>	(Müller & Troschel, 1842)	Circumtropical		2006 Ben Souissi & Zaouali, 2007	Established
Animalia: Ascidiacea					
<i>Cystodytes philippinensis</i>	Herdman, 1886	Circumtropical	?	1998 Meliane, 2002	Cryptogenic
<i>Microcosmus exasperatus</i>	Heller, 1878	Indo-Pacific	?	1998 Meliane, 2002	Established
<i>Trididemnum savignii</i>	(Herdman, 1886)	Circum (sub) tropical	?	1953 Pérès, 1954	Established
<i>Microcosmus squamiger</i>	Michaelsen, 1927	Circumtropical	1963 Monniot, 1981	2010 Chebbi <i>et al.</i> , 2010	Established
Animalia: Actinopterygii					
<i>Acanthopagrus bifasciatus</i>	(Forsskål, 1775)	Indo-Pacific	2010 Ben Souissi <i>et al.</i> , 2014a		Casual
<i>Alepes djedaba</i>	(Forsskål, 1775)	Indian	?	2012 Hattour & Bradai, 2013	Established
<i>Atherinomorus forskalii</i>	(Rüppell, 1838)	Indo-pacific	?	2005 Ben Souissi <i>et al.</i> , 2006b	Established
<i>Equulites klunzingeri</i>	(Steindachner, 1898)	Indian	?	1986 Roux, 1986	Casual
<i>Fistularia commersonii</i>	Rüppell, 1838	Indo-Pacific	2004 Charfi-Cheikhrouha, 2004	2002 Ben Souissi <i>et al.</i> , 2004b	Established
<i>Hemiramphus far</i>	(Forsskål, 1775)	Indo-Pacific	2003 Charfi-Cheikhrouha, 2004	2010 Ben Souissi <i>et al.</i> , 2010	Established
<i>Hyporhamphus affinis</i>	(Günther, 1866)	Indo-Pacific	?	2007 Kinzelbach, 2007	Casual
<i>Lagocephalus sceleratus</i>	(Gmelin, 1789)	Indo-Pacific	2011 Ben Souissi <i>et al.</i> , 2014b	2010 Jribi & Bradai, 2012	Established
<i>Lagocephalus guentheri</i>	Miranda Ribeiro, 1915	Indo-Pacific	2004 Charfi-Cheikhrouha, 2004	?	Established
<i>Pampus argenteus</i>	(Euphrasen, 1788)	Indo-Pacific		2007 Mili <i>et al.</i> , 2014	Casual
<i>Parexocoetus mento</i>	(Valenciennes, 1847)	Indo-Pacific		1999 Ben Souissi <i>et al.</i> , 2004b	Casual
<i>Pempheris rhomboidea</i>	Kossmann & Räuber, 1877	Indo-Pacific		2001 Bradai & Bouain, 2001	Established
<i>Priacanthus hamrur</i>	(Forsskål, 1775)	Indo-Pacific		1980 Abdelmouleh, 1981	Casual
<i>Saurida lessepsianus</i>	Russell, Golani, Tikochinski, 2015	Indo-Pacific	2014 Boughedir <i>et al.</i> , 2015	2004 Ben Souissi <i>et al.</i> , 2005a	Established
<i>Scomberomorus commerson</i>	(Lacepède, 1800)	Indo-Pacific	2004 Ben Souissi <i>et al.</i> , 2006c		Casual
<i>Siganus luridus</i>	(Rüppell, 1829)	Indian	1969 Ktari-Chakroun & Bouhlal, 1971	1974 Ktari & Ktari, 1974	Established
<i>Siganus rivulatus</i>	Forsskål & Niebuhr, 1775	Red Sea	2010 Personal observation (Gulf of Tunis + Galite)	1974 Ktari & Ktari, 1974	Established
<i>Sphyræna chrysoaenia</i>	Klunzinger, 1884	Indo-Pacific	?	2002 Bradai <i>et al.</i> , 2004a	Established
<i>Stephanolepis diaspros</i>	Fraser-Brunner, 1940	Red Sea	2004 Bdioui <i>et al.</i> , 2004	1966 Chakroun, 1966	Established
<i>Upeneus pori</i>	Ben-Tuvia & Golani, 1989	Indian	?	2003 Ben Souissi <i>et al.</i> , 2005b	Established
Animalia: Elasmobranchii					
<i>Glaucoctegus halavi</i>	(Forsskål, 1775)	Indo-Pacific		2004 Ben Souissi <i>et al.</i> , 2007	Casual

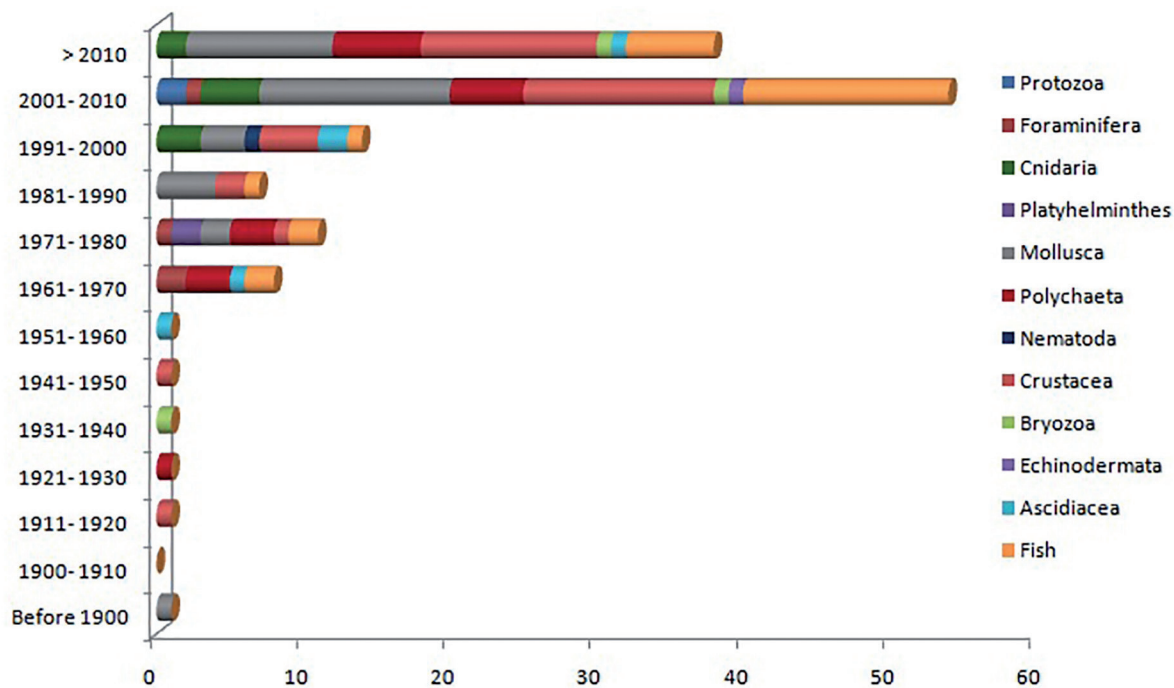


Fig. 3: Number of new introductions per decade/per area of alien fauna in Tunisian waters, according to the division of the Mediterranean by the MSFD based on the reported year of first sighting.

part of the shell is brown and smooth. Aperture is light to intense carmine-pink edged with a milky-white band. The ventrum is flat. The Tunisian shell length is 40 mm.

Morula aspera (Lamarck, 1816) (Fig. 4 E)

More than 50 specimens of *M. aspera* were collected among the biofouling on cages from shore aquaculture in Zarzis (Gulf of Gabès) (33.487928°N, 11.12264°E). The shells of Tunisian specimens are thick and have a white spiral with numerous dark brown nodules, having the appearance and the shape of a blackberry. Aperture violet with generally five teeth on the inner lip. Shell lengths varied between 9 and 15 mm.

Calcinus latens (Randall, 1840)

Two specimens of the Indo-Pacific hermit crab *Calcinus latens* were collected in the shell of the native *Stramonita haemastoma* in southern coasts of Tunisia (Djerba Island) (33.869908°N, 10.964232°E). Shield length varied between 6.9 and 7 mm. Rostrum acute. Ocular peduncles long, slender; ocular acicles small, simple. Left cheliped with outer face of palm naked, smooth, granular; upper margin variously armed with spines, spinules, tubercles, granules. Right cheliped with five strong spines on upper margin of palm; upper margin of carpus carinate and spinose. Shield greenish-gray, deep green to dark blue with pale areas. Ocular peduncles pale orange. Antennular peduncles bright blue with darker green band.

Actaeodes tomentosus (H. Milne Edwards, 1834)

This Lessepsian crab was recently collected in shallow waters of Rhodes Island, Greece for the first time in the Mediterranean Sea (Corsini-Foka & Kondylatos, 2015). Concomitantly in January 2015, three specimens (two non-ovigerous females and one male) were sampled in the marina of Hammamet (36.372239°N, 10.548254°E). With this second occurrence, the species can be considered as established in the Mediterranean Sea. This crab is easily recognized by its numerous dark granules throughout the carapace and appendages and especially on the outer face of both movable and fixed dactyls. Morphological characters of Tunisian specimens follow the description given by Serène (1984).

Other alien first records in Tunisian waters

A large bloom (> 1000 specimens) of the Lessepsian scyphomedusa *Cassiopea andromeda* was observed in northern Tunisia in Haouaria, near the Marine Protected Area of Zembra (WMED). This species is added to the worst blooms of alien jellyfish *Rhopilema nomadica* already reported in Tunisia (Daly-Yahia *et al.*, 2013).

To the previous inventory of polychaetes reported by Zghal & Ben Amor (1980) and updated by Zghal & Bouaziz-Azzouna (1984), Ayari *et al* (2009), Zaabi *et al* (2012), five newly recorded annelids were added: *Leodice antennata*, *Lysidice collaris* and *Syllis hyllebergi*, of Indo-Pacific Ocean origin, were collected in the Gulf of Gabès (CMED) while *Hydroïdes operculatus* and *Neop-*

seudocapitella brasiliensis were collected in the Gulf of Tunis (WMED). Complementary surveys conducted on macrobenthic faunal assemblages in the Gulfs of Gabès and Tunis allowed us to confirm the settlement of the new polychaete records.

Based on previous knowledge of Tunisian Bryozoa (Canu & Bassler, 1930; Seurat, 1934; Azzouz, 1973; D'Hondt & Mascarell, 2004; Ayari-Kliti *et al.*, 2012), *Crisularia serrata*, of Indo-Pacific origin, was cited for the first time among alien bryozoans. It was collected in large numbers since 2013 in the Gulf of Gabès including Boughrara lagoon. In addition, a second species, considered for a long time as native, *Amathia verticillata*, originated from the Caribbean Sea, was recently proven as an invasive alien elsewhere, including the Mediterranean Sea (Galil & Gevili, 2014). These authors suggested that this bryozoan should be added to the list of the worst invasive species in the Mediterranean Sea, as it fouls on hulls and man-made structures, it is capable of rapid reproduction and may create habitat for other Non-Indigenous Species. According to Ferrario *et al.* (2014), the status of the species is debatable and should be considered as Pseudoindigenous. This species is very common in Tunisian waters especially in lagoons (Tunis and Boughrara lagoons) and considered by Zaouali and Baeten (1984) as an indicator of pollution; it impairs artisanal commercial fisheries by clogging their nets.

The genus *Ecteinascidia* is represented in Tunisia by two species, *E. turbinata* and *E. thurstoni*. *Ecteinascidia turbinata* is a native species, very common along the coast and especially in the Gulf of Gabès (Ben Othman, 1973), exploited for pharmaceutical purposes. The ascidian *E. thurstoni* is native from Indo-Pacific, established in the East Mediterranean (Zenetos *et al.*, 2011) and was recorded for the first time in 2014 in Tunisia (Gulf of Gabès).

Among the new records, four crustaceans (three decapods, one amphipod) were added to the alien species list of Tunisian coasts. In addition to the hermit crab *Calcinus latens* and the crab *Actaeodes tomentosus*, respectively cited for the first and the second time in the Mediterranean Sea, the snapping shrimp *Alpheus rapacida* (Fig. 4C), common in the Levantine basin, has reached the central Mediterranean (Gulf of Sirte) in 2010 (unpublished data) and recently the Tunisian coast in the Gulf of Gabès in 2014. The Indian Ocean amphipod *Photis lamellifera* was also collected recently at very shallow water (less than 1 m depth) in a restricted area of the Gulf of Hammamet (Table 3).

Since the alien malacological fauna inventory was published by Antit *et al.* (2011), ten new species have been added with four mollusks cited for the first time in the present work. This update comprises two gastropods *Gibberulus gibberulus albus* and *Morula aspera* and two mussels *Modiolus auriculatus* and *Brachidontes pharaonis*. The latter species, recognized as one of the worst invasive mussels (Streftaris & Zenetos, 2006), was de-

tected early in Zarzis (Gulf of Gabès) (see table 3) and should be monitored to track its effects within the recipient ecosystem.

The alien ichthyofauna comprises 26 species, with five fishes recorded for the first time in Tunisian waters: *Petroscirtes ancylodon* (Fig. 4D), *Liza carinata* (Fig. 4F), *Plotosus lineatus* (Fig. 4G), *Sargocentron rubrum* and *Sphyræna flavicauda*. Eighteen species (see Table 2) have been removed from the previous lists and citations (Torchio, 1973, Ragonese *et al.*, 2001; Bradai *et al.*, 2004b; Ben Souissi *et al.*, 2005c; Ben Amor *et al.*, 2008; Mansour *et al.*, 2011; Ben Souissi *et al.*, 2011a, b; Ghanem *et al.*, *in press*) because their occurrence in the Mediterranean Sea was considered as a natural range expansion. To this latter category, *Cephalopholis taeniops* is added to fish fauna of Tunisia.

Temporal Trends

The introduction rate per group and per decade is depicted in Figure 1. Between 1900 and 1960, only six alien fauna species were recorded. From 1961 to March 2015, 130 records were documented. This increasing trend in recorded alien species is largely dependent upon scientific interest in alien species and the available expertise.

Major groups of alien fauna in Tunisia are Mollusca, Crustacea, Pisces, Polychaeta and Cnidaria (Fig. 1). Since 2000, an increasing rate was evident in the Marine Strategy Framework Directive MSFD subdivision for the Tunisian marine waters. Among the 136 alien species, 60 were reported in the northern Tunisia and 76 were observed in central and southern Tunisia. It is emphasized that the Gulf of Gabès comprises most of the latter records with 66 alien species (48.5%). Between Cape Bon and Ras Kapudia only six records were found: the mollusks *Gibberulus gibberulus albus* (Fig. 4A) and *Nerita sanguinolenta* (Fig. 4B) in Hergla and *Septoteuthis lessoniana* in Mahdia, and three fishes *Equulites klunzingeri*, *Priacanthus hamrur* and *Saurida lessepsianus* also recorded in Mahdia.

Distribution of alien species along the Tunisian coast and pathways of introduction

According to Bulleri *et al.* (2008), 'the successful invasion of a biological community appears to be the result of the relationship between native species richness and alien species' ability to colonize new habitats'. The authors postulate that habitats with low diversity or stressed ecosystems are more invadable. Indeed, most of the first records of alien species in Tunisia stem from ports and lagoons that appear to be favorable 'transit sites' (Passamonti, 1996; Enzenross & Enzenross, 2001; Ben Souissi *et al.*, 2005a, c). The success of Lessepsian invaders has been recently explained on the basis of the *Darwin naturalization hypothesis*, which is strictly related to the *biotic resistance hypothesis* (Azzurro *et al.*,

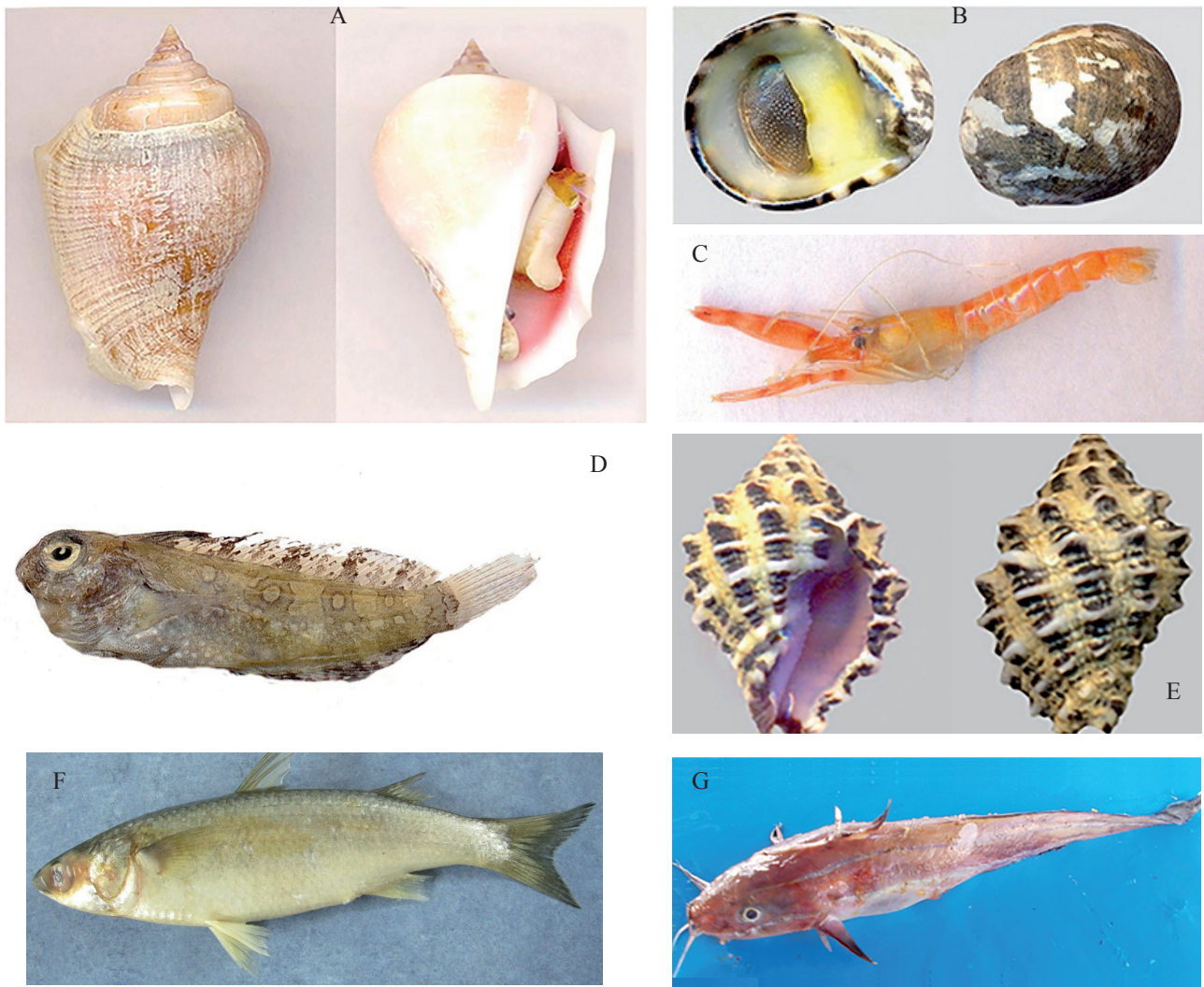


Fig. 4: Alien fauna recorded in Tunisian marine waters, A: *Gibberulus gibberulus albus*, B: *Nerita sanguinolenta*, C: *Alpheus rapacida*, D: *Petrosirtes ancyllodon*, E: *Morula aspera*, F: *Liza carinata*, G: *Plotosus lineatus*.

2014b). The areas of highest alien species preponderances were bays (Gulfs and not gulfs) considered as sheltered areas and with many ports. The main introduction pathways of alien species in Tunisia are considered shipping (in fouling and ballast water) and aquaculture. Regarding aquaculture, Tunisia has more than 24 offshore fish farms with 661 floating cages. These artificial structures provide additional support for settlement and acclimatization for alien species. Among the fouled aquaculture cages, two alien species were identified: *Nerita sanguinolenta* and *Morula aspera*. Many alien species have been reported near the oil terminal Skhira (Gulf of Gabès): the discovery there of the crabs *Libinia dubia* (Enzenross & Enzenross, 2001) and *Portunus (Portunus) segnis* (Rifi *et al.*, 2014) suggest an introduction via ballast waters. *Actaeodes tomentosus* and *Petrosirtes ancyllodon* were found respectively in the marina of Hammamet and near a pleasure boats area. Moreover, decapods especially, crabs were the most common taxa considered to have been introduced to the Mediterranean Sea as attested by Galil *et al.* (2015). Investigations in the Tunis southern

lagoon revealed ten alien crustaceans including *Eucrate crenata*, *Hemigrapsus sanguineus*, *Pilumnopus vauquelini* and *Rhithropanopeus harrisi*.

Range-expanding species

Range-expanding species are Atlantic species which enter the Mediterranean via Gibraltar Strait, unaided by human action (Zenetos *et al.*, 2012). In Tunisia, 21 species from a tropical Atlantic origin were excluded from the previous alien species inventory. This list comprises one gastropod, one isopod, one decapod and 18 fishes (Table 2). Fishes which correspond to mobile species have the highest richness (85.71%) of all range-expanding species. The same phenomenon was recently observed in the Maltese islands (Evans *et al.*, 2015). By definition, range-expanding species are ‘newcomers’ whose impact in recipient ecosystem has not been considered. Among these species are *Seriola fasciata* and *Sphoeroides pachygaster*, considered as two of the ‘worst invasive species’ in the Mediterranean, apparently with a negligible effect so far in Tunisia.

Table 2. Atlantic species excluded from alien checklists and considered as extended range into the Mediterranean reaching Tunisian waters up to March 2015.

Species	Authority, Year	Origin	1 st Tunisian sighting WMED CMED	Establishment success	Reference
Animalia: Mollusca					
Gastropoda					
<i>Siphonaria pectinata</i>	Linnaeus, (1758)	Atlanto-Mediterranean	1998 Tabarka and Bizerte	Established	Enzenross & Enzenross, 2001
Animalia: Crustacea					
Isopoda					
<i>Sphaeroma venustissimum</i>	Monod, 1931	Tropical/subtropical E Atlantic	2003 Tunis lagoon	Established	Ben Souissi <i>et al.</i> , 2005a
Decapoda					
<i>Pachygrapsus transversus</i>	(Gibbes, 1850)	Tropical/subtropical East Atlantic		2007	Established Zaouali <i>et al.</i> , 2007b
Animalia: Actinopterygii					
<i>Acanthurus monroviae</i>	Steindachner, 1876	Tropical Atlantic	2010 Gulf of Tunis	Casual	Ben Souissi <i>et al.</i> , 2011a
<i>Aluterus monoceros</i>	(Linnaeus, 1758)	Atlantic	2010 Zembra	Casual	Ben Souissi <i>et al.</i> , 2011b
<i>Chaunax suttkusi</i>	Caruso, 1989	Western and eastern Atlantic	2000	Casual	Ragonese <i>et al.</i> , 2001
<i>Cheilopogon furcatus</i>	(Mitchill, 1815)	Circumtropical		2004	Established Ben Souissi <i>et al.</i> , 2005c
<i>Kyphosus sectatrix</i>	(Linnaeus, 1758)	Tropical Atlantic		2005	Established Hattour, 2006
<i>Pisodonophis semicinctus</i>	(Richardson, 1848)	Tropical Atlantic		1998 Gulf of Gabès	Established Bradai, 2000
<i>Pontinus kuhlii</i>	(Bowdich, 1825)	Atlantic	2009	Casual	Mercader & Garcia-Rubies, 2010
<i>Psenes pellucidus</i>	Lütken, 1880	Tropical Atlantic		2014	Casual Ghanem <i>et al.</i> , <i>in press</i>
<i>Pseudupeneus prayensis</i>	(Cuvier, 1829)	Tropical Atlantic	2010	Established	Azzouz <i>et al.</i> , 2011
<i>Seriola carpenteri</i>	Mather, 1971	Tropical Atlantic		2000	Casual Pizzicori <i>et al.</i> , 2000
<i>Seriola fasciata</i>	(Bloch, 1793)	Tropical Atlantic		1996 Gulf of Gabès	Established Bradai, 2000
<i>Seriola rivoliana</i>	Valenciennes, 1833	Tropical Atlantic	2010 Bizerte	Casual	Mansour <i>et al.</i> , 2011
<i>Solea senegalensis</i>	Kaup, 1858	Tropical Atlantic	1973	Established	Torchio, 1973
<i>Sphoeroides pachygaster</i>	(Müller & Troschel, 1848)	Tropical Atlantic		1992 Gulf of Gabès	Established Bradai <i>et al.</i> , 1993
<i>Syngnathus rostellatus</i>	Nilsson, 1855	Atlantic	2006 Gulf of Tunis	Casual	Ben Amor <i>et al.</i> , 2008
<i>Zenopsis conchifer</i>	(Lowe, 1852)	Atlantic/ Pacific	2007	Casual	Ragonese & Giusto, 2007
Animalia: Elasmobranchii					
<i>Carcharhinus falciformis</i>	(Müller & Henle, 1839)	Circumtropical		2004	Casual Bradai <i>et al.</i> , 2004b
<i>Mobula japonica</i>	(Müller et Henle, 1841)	Tropical Atlantic	2014	Established	Capapé <i>et al.</i> , 2015

Establishment success and Impact

The biological invasions have been studied for more a century in the Mediterranean Sea and more than one thousand alien species (of which more than half were invasive) are recorded (Katsanevakis *et al.*, 2014). However, accounts of Invasive Aliens Species (IAS) impacts especially in ecological and economical/society terms are very recent (Streftaris & Zenetos, 2006; Davidson *et al.*, 2014; Ojaveer *et al.*, 2015; Lehtiniemi *et al.*, 2015).

The European Commission defines IAS as Invasive Alien Species causing “a significant negative impact on biodiversity as well as serious economic and social consequences” (European commission, 2013). In a recent definition (European commission, 2014), more details on IAS impacts were given as “alien species whose introduction or spread has been found, through risk assessment, to threaten biodiversity and ecosystem services, or to have a negative impact on the environment, society and

Table 3. New records of alien and range expansive species collected in Tunisian marine water (up to March 2015)

Species	Authority, Year	Origin	Year of 1 st Tunisian sighting	Site & Geographic Coordinates	WMED	CMED	Habitat	Depth	Establishment success
Alien species									
Animalia: Cnidaria									
<i>Cassiopea andromeda</i>	(Forsskål, 1775)	Red Sea/ Indo Pacific	May 2013 large bloom	Haouaria and Bay of Bizerte			Collum water	Very Shallow water <2m	Established
Animalia: Mollusca									
<i>Brachidontes pharaonis</i>	(P.Fisher, 1870)	Indian/ Red Sea	2013		Zarzis 33.531808°N, 11.114763°E		Rocky bottom & artificial structures (harbour & artificial reefs)	Very shallow depth	Established
<i>Gibberulus gibberulus</i>	(Mörch, 1850)	Indo-Pacific/ Red Sea	2011 1 specimen		La Chebba		Among vegetation including <i>Halophila stipulacea</i>	10 m depth	Casual
<i>Modiolus auriculatus</i>	(Krauss, 1848)	Indian/ Red Sea	2014 9 specimens	Cliff of Haouaria			Hard bottom among dense vegetation	< 5m	Established
<i>Morula aspera</i>	(Lamarck, 1816)	Indo-Pacific / Red Sea	2012		Zarzis 33.487928°N, 11.122649°E		Biofouling of off shore cages of pisciculture	5 m	Casual
Animalia: Polychaeta									
<i>Leodice antennata</i>	Savigny in Lamarck, 1818	Indo-Pacific	2013		Zarrat		Soft muddy bottom	?	Established
<i>Hydroïdes operculatus</i>	(Treadwell, 1929)	Indian	2013	Bay of Tunis			Hard Bottom	Shallow depth	Established
<i>Lysidice collaris</i>	Grube, 1870	Pacific/Red Sea	2013		Skhira		?	?	Established
<i>Neopseudocapitella brasiliensis</i>	Rullier & Amoureux 1979	West Atlantic / Red Sea	2013	Bay of Tunis			Soft muddy substrata	10-25 m	Established
<i>Syllis hyllebergi</i>	(Licher, 1999)	Red Sea	2013		Zarrat		Soft muddy substrata	?	Established
Animalia: Crustacea									
<i>Photis lamellifera</i>	Schellenberg, 1928	Indian	2014		Hammamet		Sandy substrata including vegetation	<1m	Established
<i>Actaeodes tomentosus</i>	(H. Milne Edwards, 1834)	Indo-Pacif / Red Sea	2015 2 nd Mediterranean record		Marina Hammamet 36.372239°N, 10.548254°E		Artificial rocky substrata- Intertidal zone	Shallow depth	Casual
<i>Alpheus rapacida</i>	de Man, 1908	Indo West Pacific	2014		Zarzis		Soft substrata	>50m	Established
<i>Calcinus latens</i>	(Randall, 1840)	Indo-Pacific / Red Sea	2015 1 st Mediterranean record		Djerba 33.869908° N, 10.964232°E		Soft substrata	Very shallow depth	Casual
Animalia: Bryozoa									
<i>Crisularia serrata</i>	(Lamarck, 1816)	Indo-Pacific	2013		Gulf of Gabès		?	?	Established
Animalia: Ascidiacea									
<i>Ecteinascidia thurstoni</i>	Herdman, 1890	Indo-Pacific	2014		Zarzis-Djerba- Lagoon of Bibans		Soft and hard substrates	Shallow depth	Casual
Animalia: Actinopterygii									

(continued)

Table 3 (continued)

Species	Authority, Year	Origin	Year of 1 st Tunisian sighting		Site & Geographic Coordinates		Habitat	Depth	Establishment success
			WMED	CMED	WMED	CMED			
<i>Liza carinata</i>	(Valenciennes, 1836)	Indian	Winter 2011	?	Kalaat Landalous	?	?	Casual	
<i>Petroscirtes ancylodon</i>	Rüppell, 1835	Indian	One specimen		Sidi Daoud		Rocky bottom with vegetation	Casual	
<i>Plotosus lineatus</i>	(Thunberg, 1787)	Indo-Pacific	Small school observed by diver fisherman		Zembra-Haouaria		?	Established	
<i>Sargocentron rubrum</i>	(Forsskål, 1775)	Indo-Pacific	2013		Zembra		?	Established	
<i>Sphyræna flavicauda</i>	Rüppell, 1838	Indian	2014				?	Established	
			5 specimens (3 females, 2 males), sizes 296-343 mm						
Range expansion Species									
Animalia: Actinopterygii									
<i>Cephalopholis taeniodon</i>	(Valenciennes, 1828)	Subtropical Atlantic	2009		Zarrat		Hard and soft substrates	?	Established
			2 specimens captured by fisherman						

the economy". Streftaris & Zenetos (2006) consider that by definition, all alien species have an impact on biodiversity. In this context, a preliminary list of the 100 'worst invasive NIS' in the Mediterranean Sea with details on their impacts was made (Streftaris & Zenetos, 2006). According to Crise *et al* (2015), the IAS perturbs the food web structure, displaces the native species (competition for space and for food), can modify the genetic pools by hybridization and can cause pests and diseases. Mckinney (1999) suggested that the loss of endemism is one of the main consequences of bio-invasion; the most vulnerable endemic species may disappear and be replaced by alien ones. Additionally, Katsanevakis *et al.* (2014) suggested that "the 'native good'- 'alien bad' view is a misconception and the role of most of the alien species in marine ecosystems is rather complex" and alien species may have positive impacts, especially by increasing biodiversity. Moreover, according to Thomsen *et al.* (2012), in a meta-analysis of sea-grasses impacts, alien invasive seaweeds had lower negative effects than native species. The complexities of species interactions require more IAS impact studies for a better understanding of this scourge. According to PERSEUS (Policy-oriented marine Environmental Research in the Southern European Seas: initiative within the 7th Framework Programme of the EC), data availability in Southern European Seas (SES) on aliens is low in initial assessments and in scientific evaluation (Crise *et al.*, 2015).

In Tunisia, the impact of IAS was poorly studied because of the recent occurrence of most species, except for some aliens which rapidly displayed an impact on the recipient environment. However, during the last decade, the effects of certain IAS became noticeable, especially for mollusks, decapods and fishes.

Pinctada radiata imbricata, one of the first non-native species recorded in Tunisian waters (Dautzenberg, 1895), was widely distributed on all Tunisian coasts (Ktari-Chakroun & Azzouz, 1971; Tlig-Zouari *et al.*, 2009). According Tlig-Zouari *et al* (2010) and Bellaaj-Zouari *et al* (2011), this pearl oyster was very abundant in the Gulf of Gabès (Ajim), the Bay of Monastir and the Gulf of Tunis. This species can be considered as one of the worst invasive species in Tunisian marine waters and recognized as a pest for fish farming in floating cages. This oyster clogs the meshes of cage nets and considerably reduces water exchange and oxygen levels. It was also considered one of the main fouling species found massively in the *Posidonia* rhizomes and on man-made structures. This species has colonized all settled artificial reefs in the Gulf of Gabès. The proliferation of the species in the Gulf of Gabès is enormous, so much so that the number of empty shells and live specimens rejected by the sea constitutes mounds designated as an "oyster cemetery" in



Fig. 5: Tons of empty shells and live *Pinctada radiata* rejected by the sea with *Posidonia oceania* (Djerba Island, Gulf of Gabès, May 2015).

AJIM (Djerba Island) (Fig. 5). To minimize the effects of this oyster and in order to capitalize on this large volume of shells, a project of using the nacreous pearl of *Pinctada radiata* as a biomedical material in orthopedic surgery was set up in 2005 after carrying out the mineralogical and organic microstructure with nacreous thickness (Bellaaj-Zouari *et al.*, 2011, 2012)

Fulvia fragilis ranked among the most widespread alien species in the Mediterranean Sea (Galil *et al.*, 2014). This species is a functional simultaneous hermaphrodite bivalve which presents continuous gonad activity, and self-fertilization seems possible. This mode of reproduction ensures the success of its installation and its invasive character. In Tunisia, this highly invasive species showed a strong ability to compete with *Acanthocardia paucicostata* and the lagoon pioneer shellfish *Cerastoderma glaucum* (Rifi *et al.*, 2011). The two bivalves *Fulvia fragilis* and *Acanthocardia paucicostata* are epigeous. Due to their short siphons, they generally find refuge on soft and turbid sea beds among vegetation to escape both predators and light. In the Bizerte lagoon, *F. fragilis* has an impact on ecosystem services where it has almost eradicated the native bivalve *A. paucicostata*, which was formerly frequent and abundant.

Since its successful establishment, the shrimp *Metapenaeus monoceros* has become very common among demersal catches in the Gulf of Gabès and became commercially valuable in the fish market since the 1990s. The shrimp pits initially colonized by the endemic shrimp *Penaeus kerathurus* are gradually being occupied by the alien shrimp. According to Chaouachi (2004), the two species are com-

petitive and have the same ecological niche. This competition has economic consequences for the gradual replacement of endemic shrimp with a higher commercial value invasive shrimp considered as by-catch (Jarbouli & Ghorbel, 1995; Missaoui & Zaouali, 1995; Ben Abdallah *et al.*, 2003; Ben Hadj Hamida-Ben Abdallah *et al.*, 2006).

Percnon gibbesi, one of the most successful invaders in the Mediterranean (Klaoudatos & Kaporis, 2014), is a potential competitor with the native crabs for resources and habitats (Sghaier *et al.*, 2011). Puccio *et al.* (2006) suggested that the feeding behavior of *P. gibbesi* give it an advantage over other Decapoda species by allowing it to explore a broader feeding niche.

The Western Atlantic native crab *Libinia dubia*, recorded in Tunisia in 1997, became dominant in the northern region of Sfax, in shallow depths. This Majidae can be considered as one of the worst invasive alien crabs in Tunisia. The observation of live crabs in the laboratory during 2014 showed that the species has a continuous spawning season with high fertility. This crab is particularly resistant and survives extreme conditions (prolonged fasting, low oxygen, degraded water quality, etc.). The preliminary study of its stomach contents showed that this species is very voracious, feeding on cephalopods, fishes, crustaceans, as well as algae. In the Gulf of Gabès, between April and July, the species rapidly proliferates, massively impacting the ecosystem services (occupation of space). An interview conducted with 105 fishermen working in the Gulf of Gabès during 2014 showed that this crab is a threat to the sustainability of artisanal fishing. Locally called “azzouza”, this crab clings strongly with its long legs and spines of its carapace and



Fig. 6: Gillnets for artisanal fishing activity completely clogged by the invasive crab *Libinia dubia* (Ajim harbour, Gulf of Gabès, February 2014)

rips the nets (Fig. 6). The loss of nets obliges fishermen to stop their work for mending. In some cases, the damage is so great that the renewal of nets becomes more profitable than their mending. Fishermen complain about the decrease in their catch, estimated at 30% loss. In addition, the fish trapped in nets with the crab was generally deteriorated and devalued by consumers.

Portunus (Portunus) segnis, recently recorded for the first time in Tunisian waters (Gulf of Gabès) by Rifi *et al* (2014), showed a highly invasive behavior with very high fertility. It expanded rapidly from Sfax (Frichet) to the entire Gulf of Gabès including Djerba Island. This blue swimming crab recently reached the Libyan shores (Shakman, pers. comm.). This crab has an economic value and the first large specimens (males and females) are beginning to be commercialized in the Tunisian fish market. The impact on ecosystem services is unknown and because of its carnivorous behavior, this species should be monitored carefully.

Among the poisonous and potentially dangerous alien species for human health, two species were reported in the Tunisian waters: the fish *Lagocephalus sceleratus* and the jellyfish *Rhopilema nomadica*. Actually, these two species

are established but not invasive; however, a serious case of poisoning by the silver-cheeked toadfish was recorded in August. This incident was immediately reported upon by the national media (Ben Souissi *et al.*, 2014a).

This update highlights that the Tunisian coasts are under heavy biological invasion of mixed origins. 136 species have been recorded of which 61.76 % are coming from the Red Sea and the Indo-Pacific areas. This number is underestimated because of the lack of knowledge and investigation. This inventory focused on the alien fauna where 21 new citations were listed for Tunisia and the Mediterranean Sea. Tunisia occupies a strategic position in the Mediterranean, a junction between the two basins, and should receive special attention by the international scientific community and policy makers in order to explain and contain the spread of alien species (in WMED, CMED and EMED) and especially to prevent further incursions. Special interest should be given to lagoons which are considered as alien species refuge areas. Indeed, Rilov & Galil (2009) recognized the Suez Canal and its lagoons as important hotspots of invasion in the western Mediterranean. In Tunisia, 16% of alien fauna was recorded for the first time in lagoons, which represent only a small area (approximately 120000 ha) compared to marine waters. Tunisia lacks national regulation regarding alien species; however, it has ratified all international conventions. To date, data on alien species are scarce and there is even less information on their impacts. The assessment of the impacts of alien species should be considered as a priority for marine management. This component requires urgent attention and significant investment. In ongoing research programs, the alien species and their impacts are not a national priority; most funding focuses living resources and the marine environment (pollution, overfishing, etc.). The rare results obtained in this work are funded as part of regional programs including those of the European Union.

Acknowledgements

We express our gratitude to scientists of Museum National d'Histoire Naturelle de Paris and researchers of Station Marine d'Endoume (Marseille) for their valued help. We wish to thank experts who confirmed taxa identification, especially Dr. Bella Galil (crustacean taxa). We are also grateful to Dr. Argyro Zenetos (Editor-in-chief; Hellenic Centre for Marine Research, Greece) for her advice and relevant comments. The authors would like to thank the fishermen for providing some alien species and their effective contribution to the awareness campaign. This research was partially funded by the European Community's FP7 (Grant Agreement 287844) for the project 'Towards COast to COast NETworks of marine protected areas (from the shore to the high and deep sea), coupled with sea-based wind energy potential' (COCONET), CIESM, and "Fondation Albert II de Monaco", tropical signals programme, and BiodivMex.

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