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Alien marine species of Libya: first inventory and new records in El-Kouf National Park (Cyrenaica) and the neighbouring areas

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Abstract

The presence of marine alien species in El-Kouf National Park and the neighbouring areas was assessed using a compilation of available information and observations, a field survey conducted in October 2010 within the framework of the MedMPAnet project and results of further monitoring during June and September 2012. A total of 9 alien species were reported: namely Rhodophyta *Asparagopsis taxiformis* (Delile) Trevisan de Saint-Léon, Chlorophyta *Caulerpa racemosa* var. *cylindracea* (Sonder) Verlaque, Huisman & Boudouresque, the crab *Percnon gibbesi* (H. Milne-Edwards, 1853) and the fishes *Fistularia commersonii* Rüppell, 1838, *Siganus luridus* (Rüppell, 1829), *Siganus rivulatus* Forsskål, 1775, *Pempheris vanicolensis* Cuvier, 1831, *Lagocephalus sceleratus* (Gmelin, 1789) and *Sphyræna flavicauda* Rüppell, 1838. Several of these species were until now unknown for the National Park. The list of alien marine species of Libya is updated and discussed. Until now 63 marine alien species have been recorded along the Libyan coastline. These include 3 Foraminifera, 3 Ochrophyta, 5 Rhodophyta, 5 Chlorophyta, 1 Magnoliophyta, 11 Arthropoda, 13 Mollusca, 1 Echinodermata and 21 Chordata. Among these Non Indigenous Species, 43 are known as established along the Libyan coast including 8 invasive, 11 casual, 5 questionable, 3 cryptogenic and 1 unknown. An in-depth study of marine organisms would substantially increase the number of alien species occurring in Libya. Monitoring of marine assemblages of MPAs provides a valuable opportunity for delving further into the knowledge of native and introduced species.

Keywords: Marine aliens, marine protected area, Libya, Mediterranean Sea.

Introduction

Marine species have been accidentally or intentionally transferred among the world's seas for as long as humans have crossed the oceans for exploration, colonization, commerce and war. However, biological invasions are being nowadays recognized as a major agent of global change following the spectacular increase of invasions by non-native marine and estuarine species in various regions of the world (Occhipinti-Ambrogi, 2007). Furthermore, biological invasions can interact with climate change and other components of global change such as increasing deposition of nitrogen and pollutants, and habitat disturbance by human activities (Vitousek *et al.*, 1997; Dukes & Mooney, 1999; Boudouresque & Verlaque, 2010). Many of the marine alien species exhibit aggressive invasive behaviour and represent significant

ecological pressures on marine and estuarine communities (Ruiz *et al.*, 1999; Streftaris & Zenetos, 2006; Sala *et al.*, 2011). In addition to alterations in ecosystem functioning and biodiversity loss, alien species can also cause serious economic (fisheries, tourism and aquaculture) and health impacts (Pimentel *et al.*, 2000).

The Mediterranean Sea is highly concerned by species introductions. Based on updated checklists (Zenetos *et al.*, 2010, 2011, 2012), a total of 986 alien species were known in the Mediterranean by December 2012: 775 in the Eastern basin, 308 in the Western basin, 249 in the Central basin and 190 in the Adriatic Sea. According to the Mediterranean Action Plan for Invasive Species (UNEP-MAP-RAC/SPA, 2005), the main known pathway/vector of species introduction into the Mediterranean Sea is the Suez Canal followed by shipping (ballast water and sediments, anchoring and fouling), aquaculture

(both marine and brackish species) and trade in live marine species (aquarium activities, fishing baits, seafood). This is in agreement with recent evaluation of pathways at Pan European level (Katsanevakis *et al.*, 2013a). Mediterranean biota are driven towards a ‘tropicalization’ as most of the alien species introduced there are of tropical affinity and origin (Bianchi & Morri, 2003). An up-to-date inventory of the alien species in the Mediterranean Sea, apart from its scientific merits, can fulfil the needs of regulatory requirements such as the EU Biodiversity Strategy to 2020 (EU, 2011) and environmental management options (Katsanevakis *et al.*, 2013b).

Libya is located in the Central Mediterranean Basin as adopted and described under the Marine Strategy Framework Directive (MSFD) (EU, 2008). Data regarding alien species are scarce and fragmented due to the lack of long term monitoring survey undertaken in a framework of national initiatives on alien species. It is worth mentioning the inventory of exotic fish reporting 16 introduced species (Ben Abdallah *et al.*, 2005) updated by Shakman & Kinzelbach (2007c).

This work reports on the alien marine species observed in El-Kouf National Park and the neighbouring areas. An updated list of alien marine species recorded from Libya is presented and discussed.

Material and Methods

El-Kouf National Park

El-Kouf National Park (herein: El-Kouf NP) is part of the Libyan coast of Cyrenaica. Located west off the city of El-Beida (N 32.7586, E 21.7484), it occupies an area of 32 000 ha, from the middle of Cyrenaica to Jar-Jar Ummah (Fig. 1). El-Kouf NP was established in 1970 under the supervision of the Arab Centre for the Studies of

Arid Zones and Dry Lands (ACSAD) and various surveys regarding the geology, wildlife and marine environment were conducted until the mid 1970s (Armsby, 1980). The coastline of El-Kouf NP covers ca. 20 km between Alhanya Village in the east (N 32.8412, E 21.5206) and Auglah Beach in the west (N 32.7712, E 21.3303). In El-Kouf NP, the marine environment differs from west to east. The western part is formed of open and long sandy beaches with sandy bottoms, rocky patches and seagrass meadows of *Posidonia oceanica* (L) Delile. The eastern part is more rugged with few sandy lagoons and beaches and a dominance of cliffs and rocky substrata.

Data collection

The presence of marine alien species in El-Kouf NP and the neighbouring areas was assessed through field surveys conducted in October 2010 and two additional surveys conducted in June and September 2012 as part of the local monitoring program.

Marine surveys were carried out in the National Park and 9 Km towards the east and 6 Km towards the West. A total of 86 stations were surveyed ranging from 0 to 46 m depth. Investigations were conducted directly from the coast (direct observation mainly in the intertidal area), using a bathyscope, by snorkelling and by scuba diving (Fig. 1). The presence of alien species was recorded. Supplementary data were obtained from professional fishermen. Alien species observed were identified and photographed.

The nomenclature adopted in this paper follows the World Register of Marine Species (WoRMS Editorial Board, 2013) and contributing databases (AlgaeBase, DAISIE, FishBase). The acclimatization (establishment) status of alien species (Established, Casual, Questionable, Cryptogenic or Invasive) in the Central Mediterranean is according to Zenetos *et al.* (2010). The date of

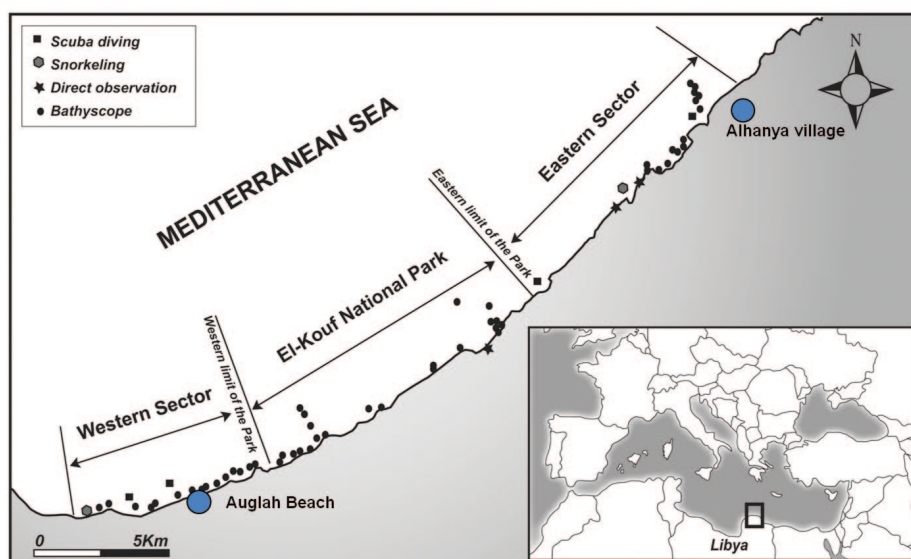


Fig. 1: Map showing the localization of the coastline of El-Kouf National Park and the surveyed stations.

first sighting in Libya (or of publication when no date of observation/collection was indicated) is also presented as well as the origin of the species.

Finally, scientific literature, websites and unpublished data were analysed to establish an updated list of the alien marine species reported from Libya. Each record has been carefully analyzed, with recourse to the published literature and, where necessary and possible, interviews with the authors.

Results and Discussion

El-Kouf National Park region

Nine alien marine species have been identified in El-Kouf NP and the neighbouring areas; namely, Rhodophy-

ta *Asparagopsis taxiformis* (Delile) Trevisan de Saint-Léon, Chlorophyta *Caulerpa racemosa* var. *cylindracea* (Sonder) Verlaque, Huisman & Boudouresque, the crab *Percnon gibbesi* (H. Milne-Edwards, 1853) and the fishes *Fistularia commersonii* Rüppell, 1838, *Lagocephalus sceleratus* (Gmelin, 1789), *Pempheris vanicolensis* Cuvier, 1831, *Siganus luridus* (Rüppell, 1829), *Siganus rivulatus* Forsskål, 1775, and *Sphyraena flavicauda* Rüppell, 1838 (Table 1; Fig. 2).

Asparagopsis taxiformis is an alien red alga exhibiting an invasive behaviour on several coasts of the Mediterranean basin (Flagella *et al.*, 2003). First reported from Libya in 1895 (De Toni, 1895), it was largely observed in El-Kouf NP and the neighbouring areas. Two cryptic taxa coexist under the name of *A. taxiformis* in the Mediterranean Sea:

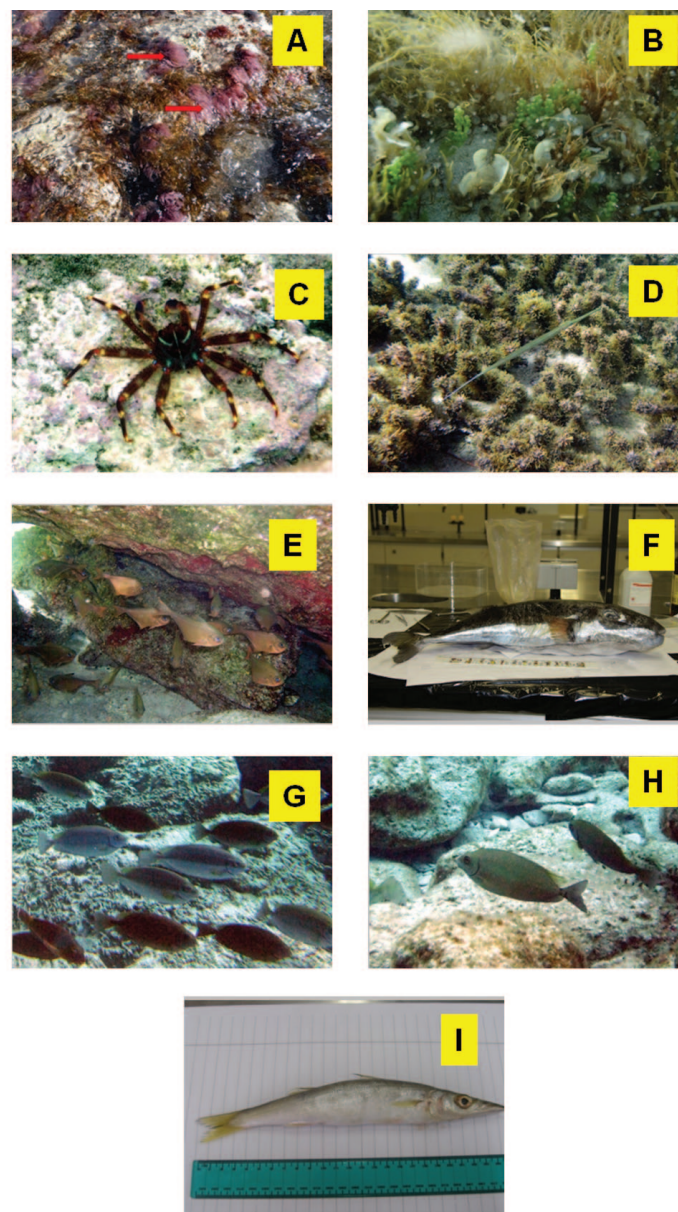


Fig. 2: Alien marine species recorded in El-Kouf National Park and neighbouring areas. A: *Asparagopsis taxiformis*; B: *Caulerpa racemosa* var. *cylindracea*; C: *Percnon gibbesi*; D: *Fistularia commersonii*; E: *Pempheris vanicolensis*; F: *Lagocephalus sceleratus*; G: *Siganus luridus*; H: *Siganus rivulatus*; I: *Sphyraena flavicauda*.

Table 1. Alien marine species reported from the El-Kouf National Park (*) and Libyan waters with the date of first sighting in Libya; world distribution and establishment success in the Central Mediterranean according to Zenetos *et al.* (2010) amended. Abbreviations: Est = established, Cas = Casual, Cry = Cryptogenic, Ques = Questionable, and Unk = Unknown. 1st sightings in bold indicate species first reported in the CMED from Libya.

Species	Authority	Distribution	1 st Libyan sighting ¹	Success	Reference
PROTOZOA					
Foraminifera					
<i>Amphisorus hemprichii</i>	Ehrenberg, 1839	Circumtropical	2008	Unk	Langer (2008)
<i>Amphistegina lobifera</i>	Larsen, 1976	Circumtropical	1979	Est	Blanc-Vernet <i>et al.</i> (1979)
<i>Coscinospira hemprichii</i>	Ehrenberg, 1839	Indo-Pacific	2008	Cry	Langer (2008)
MACROPHYTES					
Ochrophyta - Phaeophyceae					
<i>Padina boergesenii</i>	Allender & Kraft	Indo-Pacific	1974	Est	Nizamuddin (1981, as <i>P. gymnospora</i>);
<i>Padina boryana</i>	Thivy	Indo-Pacific	1974	Est	Nizamuddin (1981, as <i>P. tenuis</i>)
<i>Sypododium schimperii</i>	(Buchinger ex Kützing) Verlaque & Boudouresque	Indo West Pacific	1977	Est	Nizamuddin (1981, as <i>Spatoglossum solieri</i>); Nizamuddin & Godeh (1989, as <i>Sypododium tubruquense</i>)
Rhodophyta					
<i>Acanthophora nayadiformis</i>	(Delile) Papenfuss	Indo-Pacific	1888	Est	De Toni & Levi (1888 as <i>A. delilei</i>); Muschler (1910); Nizamuddin <i>et al.</i> (1979)
* <i>Asparagopsis taxiformis</i>	(Delile) Trevisan de Saint-Léon	Indo-Pacific	1895	Est	De Toni (1895); Nizamuddin <i>et al.</i> (1979)
<i>Chondria coeruleascens</i> ²	(J. Agardh) Falkenberg	East Atlantic	1989-1990	Est	Godeh <i>et al.</i> (1992)
<i>Lophocladia lallemandii</i>	(Montagne) F. Schmitz	Indo-Pacific	1918	Est	Petersen (1918); Nizamuddin <i>et al.</i> (1979)
<i>Polysiphonia atlantica</i>	Kapraun & J.N. Norris	N Atlantic/N Pacific	1989-1990	CyQues	Godeh <i>et al.</i> (1992, as <i>P. macrocarpa</i>)
Chlorophyta					
* <i>Caulerpa racemosa</i> var. <i>cylindracea</i>	(Sonder) Verlaque, Huisman & Boudouresque,	Indo-Pacific	1990	Inv	Nizamuddin (1991)
<i>Cladophora herpestica</i>	(Montagne) Kützing	Red Sea	1986	Ques	Nizamuddin (1988, 1991 as <i>Cladophoropsis gerloffii</i> ³)
<i>Codium fragile</i> subsp. <i>fragile</i>	(Suringar) Hariot	NW Pacific	1984	Est	Nizamuddin (1991)
<i>Codium Taylorii</i>	P.C. Silva	Indo-Pacific	1977	Est	Nizamuddin (1991, as <i>C. coralloides</i>)
<i>Ulva fasciata</i>	Delile	Warm-temperate Seas	1979	Est	Nizamuddin <i>et al.</i> (1979); Godeh <i>et al.</i> (1992)
Magnoliophyta					
<i>Halophila stipulacea</i>	(Forsskål) Ascherson	Red Sea	<2009	Est	UNEP/ MAP-RAC/SPA (2009); Sghaier <i>et al.</i> (2011)
CRUSTACEA					
Amphipoda					
<i>Cymadusa filosa</i>	Savigny, 1816	Indo-Pacific	1939	Cry	Maccagno (1939)
<i>Hamimaera hamigera</i>	(Haswell, 1879)	Indo-Pacific	1972	Cas	Ortiz & Petrescu (2007)
Cirripedia					
<i>Tetraclita rufotincta</i>	Pilsbry, 1916	Indo-Pacific	2007	Cas	Zaouali <i>et al.</i> (2007a)
Copepoda					
<i>Paraeuchaeta concinna</i>	(Dana, 1849)	Indo-Pacific	1990	Cas	Halim, 1990

(continued)

(continued) Table 1.

Species	Authority	Distribution	1 st Libyan sighting ¹	Success	Reference
Decapoda					
<i>Grapsus granulosus</i>	H. Milne-Edwards, 1853	Red Sea	2006	Cas	Zaouali et al. (2007b)
* <i>Percnon gibbesi</i>	(H. Milne-Edwards, 1853)	W Atlantic	2004	Inv	Elkrwe et al. (2008)
<i>Plagusia squamosa</i>	(Herbst, 1790)	Indo-Pacific	2006	Est	Zaouali et al. (2007b)
<i>Eucrate crenata</i>	(De Haan, 1835)	Indo-Pacific	1999	Est	Zgozi et al., 2002
Isopoda					
<i>Apanthura sandalensis</i>	Stebbing, 1900	Indo-Pacific	1976	Est	Negoescu (1981)
<i>Paradella diana</i>	(Menzies, 1962)	Indo-Pacific	2001	Cas	Zgozi et al. (2002)
Stomatopoda					
<i>Erygosquilla massavensis</i>	(Kossmann, 1880)	Red Sea-Indian	2002	Est	Zgozi et al. (2002)
MOLLUSCA					
Bivalvia					
<i>Malleus (Mahufundus) regula</i>	(Forsskål in Niebuhr, 1775)	Indo-Pacific	2001	Est	Giannuzzi-Savelli et al. (2001)
<i>Pinctada imbricata radiata</i>	(Leach, 1814)	Indo-Pacific	1913	Inv	Monterosato (1917)
<i>Fuvia fragilis</i>	(Forsskål in Niebuhr, 1775)	Indo-Pacific	1997	Inv	Zgozi et al. (2002)
Gastropoda					
<i>Bursatella leachi</i>	Blainville, 1817	Red Sea-Indian	2000	Inv	Zgozi et al. (2002)
<i>Cellana rota</i>	(Gmelin, 1791)	Red Sea-Indian	2007	Ques	Zaouali et al. (2007b)
<i>Clypeomorus bifasciata</i>	(G.B. Sowerby II, 1855)	Indo-Pacific	1994	Cas	Giannuzzi-Savelli et al. (1997)
<i>Conomurex persicus</i>	(Swainson, 1821)	Indian Ocean	2006	Est	Ben Souissi et al. (2007as <i>Strombus persicus</i>)
<i>Conus fumigatus</i>	Hwass in Bruguière, 1792	Red Sea	1986	Cas	Röckel (1986)
<i>Erosaria turdus</i>	(Lamarck, 1810)	Red Sea-Indian	2007	Est	Ben Souissi et al. (2007)
<i>Haliotis pustulata cruenta</i>	Reeve, 1846	Red Sea-Indian	1994	Cas	Giannuzzi-Savelli et al. 1994
<i>Monetaria annulus</i>	(Linnaeus, 1758)	Indo-Pacific	2006	Ques	Ben Souissi et al. (2007, as <i>Cypraea annulus</i>)
<i>Nerita sanguinolenta</i>	Menke, 1829	Red Sea	1994	Cas	Giannuzzi-Savelli et al. (1994)
Polyplacophora					
<i>Acanthopleura gemmata</i>	(Blainville, 1825)	Indo-Pacific	2006	Ques	Zaouali et al. (2007b)
ECHINODERMATA					
<i>Ophiocoma scolopendrina</i>	(Lamarck, 1816)	Red Sea-Indian	2007	Ques	Zaouali et al. (2007b)
FISH					
Actinopterygii					
<i>Alepes djedaba</i>	(Forsskål, 1775)	Indo-Pacific	1990	Est	Ben Abdallah et al. (2005)
<i>Atherinomorus forskalii</i>	(Rüppell, 1838)	Red Sea	1929	Est	Norman (1929) as <i>Prasenus pinguis</i>
<i>Crenidens crenidens</i>	(Forsskål, 1775)	Red Sea-Indian	1999	Est	Al-Hassan & El-Silimi (1999)
* <i>Fistularia commersonii</i>	Rüppell, 1838	Indo-Pacific	2004	Inv	Ben Abdallah et al. (2005)
<i>Hemiramphus far</i>	(Forsskål, 1775)	Indo-Pacific	2006	Est	Shakman & Kinzelbach (2006, 2007b,c), Shakman (2008)
<i>Herklotsichthys punctatus</i>	(Rüppell, 1837)	Red Sea	2005	Est	Shakman & Kinzelbach (2007b,c)
* <i>Lagocephalus sceleratus</i>	(Gmelin, 1789)	Indo-Pacific	2006	Cas	Kacem-Snoussi et al. (2009)
<i>Lagocephalus suezensis</i>	Clark & Gohar, 1953	Red Sea-Indian	2009	Cas	Kacem-Snoussi et al. (2009)

(continued)

(continued) Table 1.

Species	Authority	Distribution	1 st Libyan sighting ¹	Success	Reference
<i>Liza carinata</i>	(Valenciennes, 1836)	Red Sea-Indian	2005	Est	Shakman & Kinzelbach (2007b,c)
<i>Parexocoetus mento</i>	(Valenciennes, 1847)	Indo-Pacific	1966	Est	Ben Tuvia (1966)
* <i>Pempheris vanicolensis</i>	Cuvier, 1831	Indo-Pacific	2004	Est	Ben Abdallah <i>et al.</i> (2004)
<i>Sargocentron rubrum</i>	(Forsskål, 1775)	Indo-Pacific	1968	Cas	Štirn (1970)
<i>Saurida undosquamis</i>	(Richardson, 1848)	Indo-Pacific	1982	Est	Zupanovic & El-Buni (1982)
<i>Scomberomorus commerson</i>	(Lacepède, 1800)	Indo-Pacific	1974	Est	Ben Abdallah <i>et al.</i> (2003)
* <i>Siganus luridus</i>	(Rüppell, 1829)	Red Sea-Indian	1968	Est	Štirn (1970)
* <i>Siganus rivulatus</i>	(Forsskål, 1775)	Red Sea	1968	Est	Štirn (1970)
* <i>Sphyræna flavicauda</i>	Rüppell, 1838	Indo-Pacific	1998	Est	Ben Abdallah <i>et al.</i> (2003)
<i>Sphyræna chrysoaetia</i>	Klunzinger, 1884	Indo-Pacific	1968	Est	Štirn (1970); Shakman & Kinzelbach (2007b, c)
<i>Stephanolepis diaspros</i>	Fraser-Brunner, 1940	Red Sea	1965	Est	Zupanovic & El-Buni (1982)
<i>Upeneus moluccensis</i>	(Bleeker, 1855)	Indo-Pacific	1968	Est	Štirn (1970)
<i>Upeneus pori</i>	Ben-Tuvia & Golani, 1989	Red Sea-Indian	1994	Est	Ben Abdallah <i>et al.</i> (2005)

1. When no date of record is mentioned, we report the date of publication.

2. Native and introduced populations probably occur in the Mediterranean Sea.

3. Described from Libya, *C. gerloffii* is very close to *Cladophora herpestica* and might be merely a junior synonym of this species. However, according to Leliaert and Coppejans (2006), *C. gerloffii* would be a junior synonym of *Cladophoropsis membranacea*.

4. *Sphyræna flavicauda* Rüppell, 1838 is considered a synonym of *S. obtusata* by Doiuchi and Nakabo (2005, 2007).

5. *Sphyræna chrysoaetia* is considered a synonym of *S. pinguis* by Doiuchi and Nakabo (2005, 2007).

the alga described in 1813 from Alexandria and confined to the eastern Mediterranean Basin (Egypt, Lebanon, Syria and likely Libya) and a more recently introduced taxon exhibiting an invasive behaviour in the western basin and the Adriatic Sea. Molecular studies showed that the first might be of Atlantic provenance, via the Strait of Gibraltar, whereas the second colonized the Mediterranean from the Indo-Pacific Ocean, probably via the Suez Canal (Lessepsian species) (Ni Chualáin *et al.*, 2004; Andreakis *et al.*, 2007). Identification of *A. taxiformis* spp occurring in El-Kouf NP requires further investigation.

Caulerpa racemosa var. *cylindracea* was first observed in the Mediterranean Sea in Libya (Tajora, Tripoli) in 1990 on sandy rocky platforms in association with *Cystoseira* species and *Flabellia petiolata* (Turra) Nizamuddin (Nizamuddin, 1991). Shipping (ballast water) and aquaria trade are considered as possible vectors of introduction from the Indo-Pacific Ocean. Twenty three years after its discovery in Libya, *C. racemosa* var. *cylindracea* is present all around the Mediterranean Basin and in the close Atlantic Ocean (Canary Islands) (Klein & Verlaque, 2008; Marc Verlaque unpublished data). It is probably one of the major invaders ever observed in the Mediterranean Sea. In the El-Kouf NP, *C. racemosa* var. *cylindracea* was observed during a diving session along the coast; it was found in small patches in two areas at a depth of less than three meters and mixed with other native algae species such as *Padina* sp. and *Cystoseira* sp. The two areas were sheltered by the small rocky islands close to the coastline.

Percnon gibbesi is one of the most widely distributed Percnidae (Crustacea: Decapoda) in the world, with a range extending from California to Chile, from Florida to Brazil, and from Madeira to the Gulf of Guinea (Manning & Holthuis, 1981). It was first reported in the Mediterranean Sea in 1999 at Linosa Island (Relini *et al.*, 2000). Its presence along the Libyan coast was first recorded at Alhanya in 2004 (Elkrwe *et al.*, 2008) before to be mentioned in many other localities in the Cyrenaica (Katsanevakis *et al.*, 2011).

Since then, its abundance has increased rapidly, and it has been observed at a few other sites. During our survey, a total of 107 individuals of various size classes were recorded in El-Kouf NP. Currently *P. gibbesi* seems well established up to Ras Lateen near the Gulf of Bombah (N 32.6250, E 23.1140) while its western distribution beyond the Cyrenaica remains to be investigated.

The bluespotted cornetfish *Fistularia commersonii* is an Indo-Pacific species that invaded the Mediterranean Sea through the Suez Canal. It was first observed in Israel in 2000 (Golani *et al.*, 2002). Since then, it has been spreading throughout the Mediterranean Sea (Azzurro *et al.*, 2012). Reported in Libya since 2004 (Ben Abdallah *et al.*, 2005), *F. commersonii* was not yet abundant in the El-Kouf NP region but it started to appear in local fishing markets.

Originating in the tropical Indo-Pacific Ocean,

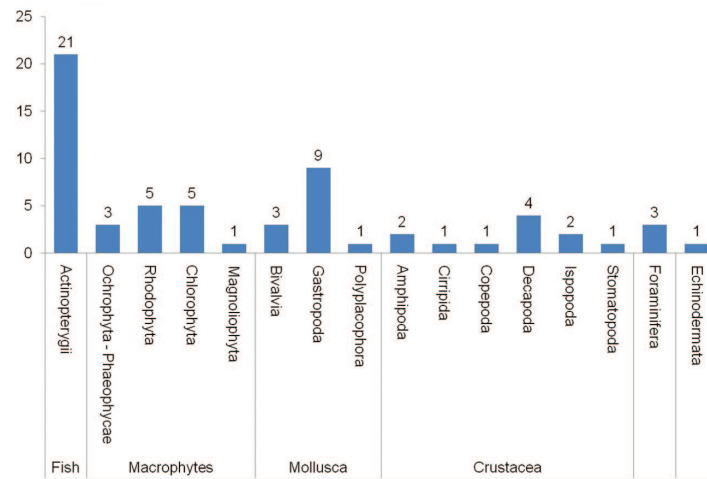


Fig. 3: Marine alien species in Libyan waters by taxonomic group.

Lagocephalus sceleratus has been listed as one of the 100 “worst invasive species” of the Mediterranean Sea (Streftaris & Zenetos, 2006). Since its first report along the coast of Turkey in 2003 (Akyol *et al.*, 2005), new findings have revealed that this Lessepsian species is now very common along the Levantine coasts of Turkey (Bilecenoglu *et al.*, 2006) and the south Aegean (Corsini *et al.*, 2006; Petrou *et al.*, 2011). In Libya, *L. sceleratus* was first collected in 2006 (Kacem-Snoussi *et al.*, 2009). Fishermen caught the fish in 2010 inside and outside the Ain Al Ghazala Lagoon and off Ain Al Ghazala (Milazzo *et al.*, 2012). *L. sceleratus* was not observed *in situ* in El-Kouf NP but specimens were caught by fishermen working in the area in October 2010.

The sweeper fish *Pempheris vanicolensis* is an Indo-Pacific species that invaded the Mediterranean Sea through the Suez Canal. It was first recorded in Lebanon in 1979 (Mouneimne, 1979). In Libya where it was first reported in 2004 (Ben Abdallah *et al.*, 2004), *P. vanicolensis* is frequently observed in relatively high abundance (Shakman & Kinzelbach, 2007a-c). In the surveyed area, the species formed small schools in cracks and underwater caves. Locally, the species has no economic value.

The dusky spinefoot *S. luridus* and the marbled spinefoot *S. rivulatus* are widely distributed in the Indian Ocean and the Red Sea, respectively. First observed in the Mediterranean Sea in 1931 and 1924, respectively (Ben-Tuvia, 1964), these two Lessepsian species are considered as invasive in the Eastern and Central Mediterranean basins where they have become common commercial fishes (Golani *et al.*, 2002; Ben Abdallah *et al.*, 2003; Streftaris & Zenetos, 2006; Shakman *et al.*, 2008). *Siganus luridus* and *S. rivulatus* were first reported from Libya in 1968 (Štirn, 1970). According to Ben Abdallah *et al.* (2003), *S. luridus* appeared in 1973 in commercial catches and became one of the most abundant species in captures by trammel and gill nets, though its abundance decreases towards the west. Since then *Siganus* spp.

have become very common in Libyan waters probably outcompeting the two native herbivorous species *Sarpa salpa* (Linnaeus, 1758) and *Sparisoma cretense* (Linnaeus, 1758) (Štirn, 1970; Shakman & Kinzelbach 2007b). *Siganus rivulatus* is mostly recorded from the eastern littoral of Libya where it is found in small groups in inshore waters close to sandy bottoms covered by seagrasses and caught in small quantities mixed with *S. luridus* (Ben Abdallah *et al.*, 2003), while *S. luridus* seems to be more present in central and western parts of the littoral (Shakman & Kinzelbach, 2007c). Both species were abundant in El-Kouf NP, especially *S. luridus* - numerous schools were observed in different parts of the surveyed area.

Due to their similar morphology, alien barracuda species often cause confusion. According to the distribution of the two species in the CIESM Atlas of exotic species (Golani *et al.*, 2002), the common species in Libya should be *S. chrysotaenia* collected since 1968 (Štirn 1970); *S. flavicauda* was collected three decades later (Ben Abdallah *et al.*, 2003). To-date, both species are common (in terms of abundance) and largely distributed in Libyan waters (Shakman & Kinzelbach, 2007b, c). The yellowtail barracuda was not observed *in situ* in El-Kouf NP but specimens were caught by fishermen working in the area in June 2012.

Inventory of the alien marine species of Libya

A comprehensive inventory of marine alien species for Libyan waters, along with their acclimatization status, origin and date of first sighting (or publication when no date of record is mentioned) was compiled.

Until now 63 marine aliens species have been recorded along the Libyan coastline. These include 3 Foraminifera, 14 macrophytes, 11 Crustacea, 13 Mollusca, 1 Echinodermata and 21 fishes (Actinopterygii) (Table 1, Fig. 3). Among these Non Indigenous Species, 43 are known as established including 8 invasive, 11 casual, 5 questionable, 3 cryptogenic and 1 unknown (Table 1).

Fishes rank first probably because they are the most studied taxon among alien marine organisms, and they highly contribute to local fishery activities (Shakman & Kinzelbach, 2007b). Besides the 16 species recorded by Ben Abdallah *et al.* (2005), 4 more species were added to the list at a later date: *Hemiraphus far* (Shakman & Kinzelbach, 2006); *Liza carinata* (Shakmam & Kinzelbach, 2007b, c), *L. sceleratus* and *L. suezensis* (Kacem-Snoussi *et al.*, 2009; Ben Abdallah *et al.*, 2011). To these we should add *Atherinomorus forskalii* reported by Norman (1929) as *Prasenus pinguis* (Lacepède, 1803). Of the 21 alien fishes, that all are Actinopterygii, 18 have established populations while 3 species (*Sargocentron rubrum*, *Lagocephalus sceleratus* and *L. suezensis*) are only known from one or two records. However this could be the result of the limited number of studies. For example, *L. sceleratus* is established in the Central Mediterranean and is expanding its geographic range to the Ionian Sea (Zenetos *et al.*, 2013). Other species such as *Cephalopholis taeniops* (Valenciennes, 1828), *Seriola rivoliana* Valenciennes, 1833, *Sphoeroides pachygaster* (Müller & Troschel, 1848) and *Synaptura lusitanica* (Capello, 1868) were not considered in this study as they are of Atlantic origin and it has been argued that their presence in the Mediterranean is due to range expansion. The list of newly introduced fish species in Libya is non-exhaustive. The latest record is that of the Bermuda sea chub *Kyphosus sectatrix* (Linnaeus, 1758) (Elbarassi *et al.*, 2013). Zupanovic & El-Bini (1982) have reported *Pomadasyx olivaceum* Day, 1975 based on a single specimen collected off Zwara, Tripolitanian coast. This record has been listed in the DAISIE inventory as *Pomadasyx stridens* (Forsskål, 1775). In the absence of voucher specimens and based on the opinion of local experts who report only its congeneric *Pomadasyx incicus*, a native Mediterranean species, the record of *P. stridens* is herein excluded.

Macrophytes rank second on the list. The analysis of literature (Nizamuddin *et al.*, 1979, 1994; Nizamuddin, 1981, 1985, 1991, 1995; Shameel, 1983; Zarmouth & Nizamuddin, 1991; Godeh *et al.*, 1992, 2009; Ribera *et al.*, 1992; Gallardo *et al.*, 1993; Nizamuddin & El Menifi Fathalla, 1993; Babbini & Bressan, 1997; Gómez Garreta *et al.*, 2001; Taskin *et al.*, 2012) gave a list of 240 native marine taxa of macrophytes. Four species not corresponding to valid taxa have been excluded, *i.e.* *Chaetomorpha urbica* (Zanardini) Kützing, *Cladophora catenata* (J. Agardh) Hauck, *Cladophoropsis puillis* (Kütz.) Boergesen and *Gracilaria verrucosa* var. *ramulosa* (C. Agardh) M.P. Reis, as well as the nine following alien taxa reported by Nizamuddin (1991) and Godeh *et al.* (1992, 2009), which we considered as misidentifications [*Bryopsis caespitosa* Suhr ex Kützing (as *Bryopsis caespitosa* Suhr in Kützing), *Bryopsis pennata* var. *leprieurii* (Kützing) Collins & Hervey (as *Bryopsis leprieurii* Kützing), *Chaetomorpha indica* (Kützing) Kützing, *Chaetomorpha melagonium* (F. Weber & Mohr) Kützing, *Chon-*

dria oppositoclada E.Y. Dawson, *Dasya villosa* Harvey, *Gastroclonium ovatum* (Hudson) Papenfuss, *Laurencia laxa* (R. Brown ex Turner) Gaillon (as *Laurencia laxa* Kützing) and *Ulva taeniata* (Setchell) Setchell & N.L. Gardner]. In this study, we have listed a total of 14 alien macrophytes, which represent 5.5 % of the Libyan marine macroflora. All these alien species are established except for *Cladophora herpestica* and *Polysiphonia atlantica* that are questionable and cryptogenic/questionable, respectively. This group includes one of the most invasive alien species in the Mediterranean, namely *Caulerpa racemosa* var. *cylindracea*.

Molluscs are known to be one of the dominant alien groups in the Mediterranean (Zenetos *et al.* 2012). Here, they rank third on the list, with only six established species, including two invasive bivalves (*Pinctada imbricata radiata* and *Fulvia fragilis*) and one invasive gastropod (*Bursatella leachii*), the remaining ones being casual or questionable. The presence of the limpet *Cellana rota* and the cowry *Monetaria annulus* reported by Ben Souissi *et al.* (2007) is questionable because *C. rota* can be easily confused with the native limpets, and the majority of old records of *M. annulus* were based on transported shells (the species was one of the molluscan shells most often carried around, as currency or ornaments) (Gofas & Zenetos, 2003).

Crustaceans with 9 alien species rank fourth. Four species are established and the other ones are casual or questionable. This group includes one of the most invasive alien species in the Mediterranean, namely the decapod *Percnon gibbesi*.

Finally, Foraminifera and Echinodermata included 3 and 1 alien species and occupy the fifth and the sixth places, respectively. The absence of taxonomic groups such as the Annelids, one of the major phyla ranking third in terms of contributors to Mediterranean alien biota [with 132 species], is indicative of the lack of taxonomic experts in the area. It is also worth noting the absence or rarity of zooplanktonic species such as Cnidaria and Copepoda.

Up to December 2012, a total of 249 alien species were known from the Central Mediterranean (Zenetos *et al.*, 2012). The majority of alien species in the Libyan waters are of Indo-Pacific origin (53%), followed by Red Sea – Indian Ocean species (16%), Red Sea species (14%), Circum-tropical (3%). Less than 5% of the alien introduced species in Libya originate in the Atlantic as opposed to the Atlantic species expanding their distribution in the Mediterranean (reaching Libya) without human intervention as a result of climate change. Libya, and globally the strait of Sicily, has a special geographical position in the Mediterranean. For approximately 44 of the 63 alien species listed here, the first Libyan record was also the first for the central Mediterranean. This highlights the importance of the region for monitoring introductions in the Mediterranean. This sector is regarded as an area of biogeographical transition (Bianchi, 2007) and it is located at the crossroads between different Mediterranean basins and hydrographic conditions. In this

area, significant changes have occurred in the biological communities and many alien species have appeared in the last few years. Lessepsian migration through the Suez Canal probably has a conspicuous influence on Libyan marine biodiversity, but Libya also seems to harbour alien species arriving from the West (Atlantic). In both cases, a warm temperate or subtropical affinity of most species is evident.

Compared to other Mediterranean regions, the number of alien species recorded in Libya is low: 63 species versus 107 in Tunisia and 232 in Egypt (Katsanevakis *et al.*, 2012; UNEP-MAP-RAC/SPA, 2013). However, this number is certainly underestimated for various reasons. The scientific effort of investigation, including taxonomic expertise availability is limited; small-sized Lessepsian immigrants (macrophytes and invertebrates) have been poorly studied and many species probably remain undiscovered. Moreover, the deep benthic assemblages were not investigated. As an example, the divergence between Tunisia and Libya in numbers is more obvious in Decapoda (17 in Tunisia vs. 4 in Libya), Bivalvia (7 in Tunisia vs. 3 in Libya), Gastropoda (15 in Tunisia vs 9 in Libya) (UNEP-MAP-RAC/SPA, 2013). The difference is also due to the lack of data for several groups in Libya such as Phaeophyceae, Polychaeta, Copepoda, Isopoda, Cephalopoda, Bryozoa, Cnidaria, Hydrozoa, Ascidiacea, Echinodermata, Platyhelminthes and Elasmobranchii.

Conclusion

Marine protected areas in the Mediterranean have not escaped biological invasions and most of them have been affected by introduced invasive alien species that threaten marine biodiversity (Otero *et al.*, 2013). In El-Kouf National Park, among the nine alien species recorded, *C. racemosa* var. *cylindracea*, *Siganus* spp. and *Percnon gibbesi* are classified among the major invaders of the Mediterranean. However, no data are available on the environmental impact of these species on the El-Kouf NP.

An in-depth study of marine organisms would substantially increase the number of alien species occurring in Libya, especially the proportion of Indo-Pacific species arriving via the Suez Canal. Monitoring marine assemblages of MPAs provides a valuable opportunity for further in-depth knowledge of native and introduced species.

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