Int. J. Aquat. Biol. (2019) 7(4): 180-194
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.ij-aquaticbiology.com

Original Article

Updated list of alien macrozoobenthic species along the Syrian coast

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Abstract: Marine biodiversity along the Syrian coast is affected by climate change-related temperature increase leading to the migration and entrance of alien species, especially from the Suez Canal (biological invasion). The Syrian coast is chracterized by many different types of habitats, including marine caves, midilittoral bioconstructions (*Lithophyllum byssoides* rim and vermetid tarraces), coraligenous communities, sandy dunes, rocky coast and seagrass meadows. The present study summarizes early and most recent results on the presence, distribution, abundance and conservation status of marine alien species along the Syrian coast and provides an updated list of alien macrozoobenthic species. A total of 79 alien species belonging to Mollusca, Crustacea, Tunicata, Polychaeta, Spongia, Echinodermata and Chaetognatha are reported; among them Gastropoda is being the most abundant and successful taxon. In the light of these results, some recommendations on future research directions are provided. In particular, more effort is needed to monitor and record the entrance of alien species by adopting a comprehensive national plan to study marine biodiversity and to protect local resources in the Syrian marine environment.

Article history:
Received 5 February 2019
Accepted 27 July 2019
Available online 25 August 2019

Keywords:
Marine biodiversity
Macrozoobenthos
Invasive alien species
Eastern Mediterranean Sea

Introduction

Marine biodiversity in the Mediterranean Sea is undertaking major changes due to climate change-related increase in water temperature. Local species from temperate waters disperse throughout the Mediterranean Sea, while phyto- and zoobenthic species from the warmer Red Sea enter the Mediterranean Sea through the Suez Canal. The introduction of alien species (biological invasions) is considered to be a major threat to marine biodiversity along with overfishing, pollution and habitat destruction, causing serious environmental and economic consequences (Ruiz et al., 1997; Carlton, 2000; Bax et al., 2003). There are many examples of disastrous invasions by these species that caused the loss of native species, changes in community structure and their functions, besides damages to local fishery and aquaculture.

The alien species found in the Mediterranean Sea is approaching 1,000 (Zenetos et al., 2012; Katsanevakin et al., 2016), with an introduction rate of one species every 1.5 week (Zenetos, 2010; Zenetos et al., 2012). In the Mediterranean Sea, the distribution and spread of alien species varies from country to another. They are more preponderant in the eastern basin (775 alien species) than in the western part, most of them being Lessepsian species that have entered the Mediterranean through the Suez Canal. These species include 13 taxonomic groups dominated by Mollusca (215 species), followed by crustacea (159 species) and polychaeta (132 species). Among these alien species, over 600 species are well-established in the Mediterranean Sea (Zenetos et al., 2017). Some alien invertebrates have also become dominant components of the region and greatly altered the benthic community structures (Çinar et al., 2011). These species can drastically alter the food web in the area, compete with native species for food and space, and transmit new diseases to native species (Por, 1978; Çinar et al., 2005). The Syrian coast (183 km in length) is located in the middle part of the eastern Mediterranean Sea, extending geographically from

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DOI: https://doi.org/10.22034/ijab.v7i4.556

Al-Hamedia in the south to Ras Al-Bassit in the north. The Mediterranean coast forms an integrated unit in terms of geological structure and topography. It is exposed to several environmental problems as a result of anthropological activities, which dispose untreated wastes directly into the marine environment. Hence, water pollution causes deterioration of coastal ecosystems, which influences the public health, fishing and tourism. Furthermore, the Suez Canal which is 650 km away from the Syrian coast represents a critical passage for Indian and Pacific species migrating through the Red Sea to the Mediterranean Sea, some of which settle and become highly invasive. For these reasons, the geographical distribution, dispersion and reproduction of those species along the Syrian coast has to be considered a fundamental issue to study.

Benthic habitats along the coast of Syria have been densely colonized by Lessepsian species. In addition, Tartous in the south and Lattakia in the north have large international harbours and jetties for crude oil and coal transfers. Therefore, the region is also a recipient area for ship-transferred species into the Mediterranean Sea. Over the last several years zoobenthic communities and their distributional patterns in Syria have been studied within scientific projects and various studies at littoral, sublittoral and deep sea areas. Some papers reported quantitative and qualitative attributes of zoobenthic communities (Saker and Ammar, 1996; Kucheruk et al., 1998; Saker et al., 1999, 2000) in the north sector of the Syrian coast, such as Lattakia and Al-Bassit (Torchia et al., 2004; Ammar, 2004, 2010; Ammar et al., 2008, 2011). The objective of the present study was to review, update and present a unique and updated list of alien macrozooobenthic species and taxa which have been recorded until 2018 along the Syrian coast.

Materials and Methods

We conducted a review of the alien species found between 1994 and 2018 at various depths and sites of the Syrian coast (Fig. 1). Available information was gathered from both published and unpublished works. Samples were collected either by hand or using

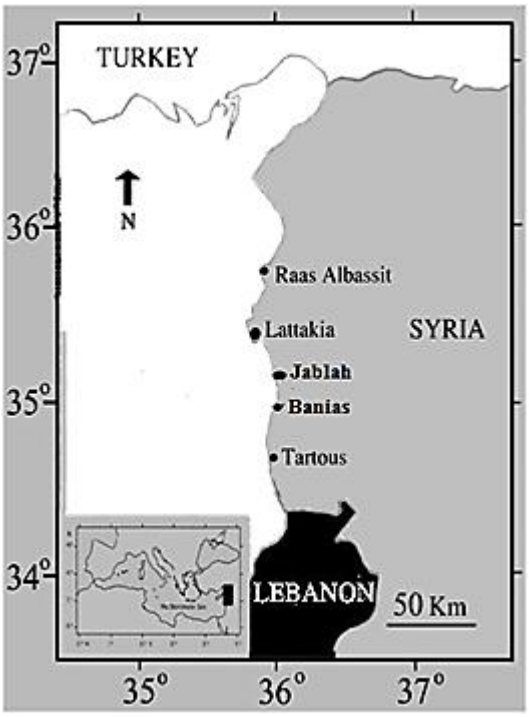

Figure 1. Map of Syrian coast.

benthic sampling devices (e.g. trawl, trammel net and grab). In addition, new soft bottom benthic samples were collected in 2015 and 2016 in the marine protected area of Ibn-Hani, north of Lattakia, at depths ranging between 15-40 m. More recent samples were collected from different areas of the Syrian coast during the year of 2018. Nomenclature follows the World Register of Marine Species (WoRMS, 2018).

Results and Discussion

Alien species along the Syrian coast: The rise of water temperatures due to climate change in the eastern shores of the Mediterranean Sea overlaps with the entry and settlement of new species in the region in several ways. These include a direct impact on individuals and populations due to changes in the local physical and chemical conditions and an indirect impact related to changes in species distribution and reproduction, and competition between local and alien species often resulting in an expansion of former.

During previous researches, which were conducted along the Syrian coast, more than 600 species belonging to 16 macro-taxa, including Porifera, Cnidaria, Bryozoa, Sipunculida, Polychaeta, Gastropoda, Bivalvia, Cephalopoda, Scaphopoda,

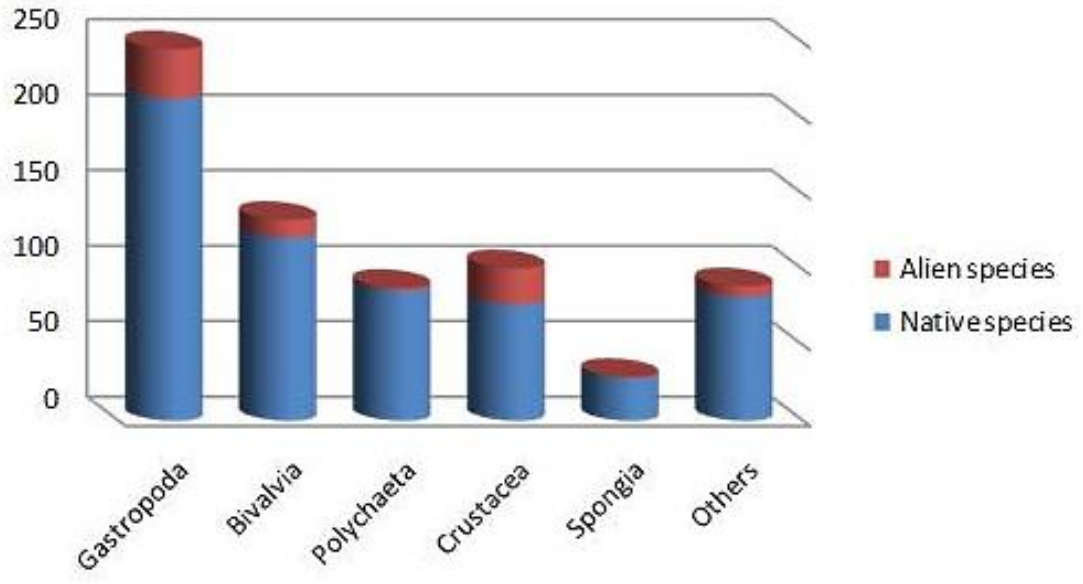

Figure 2. Number of native, alien and cryptogenic species for each taxonomic group.

Crustacea, Echinodermata, Brachiopoda, Ascidiacea and other minor taxa, were recorded at a depth up to 600 m in both hard and soft bottom (Ammar et al., 2013; Ammar, 2016). Most of these species are Atlantic and Mediterranean fauna, 79 of them being alien. The largest number of alien species in Syria belongs to Mollusca (Bitar et al., 2003; Ammar, 2004; the present study). This phylum also contributes the most of alien species in the eastern Mediterranean and European Seas (Katsanevakis et al., 2013; Nunes et al., 2014). An updated list of alien zoobenthic species found along the Syrian coast, including the time of first record, the type of habitat and depth was explained in the Table 1.

Early studies on Lessepsian migration took place along the coast of Lattakia and Banias, where 16 gastropod species, 9 bivalve species and 11 crustaceans were found (Saker and Ammar, 1994a, b; Saker and Farah, 1994). Subsequent research recorded new species belonging to several benthic taxa, including Mollusca, Crustacea, Polychaeta, Spongia and Chaetognata (Hassan et al., 2008; Arabia, 2011; Ammar et al., 2013; Ammar, 2016a, b). Currently, alien species of zoobenthos represent almost 11.55% of the total number of zoobenthos in the Syrian coast. The great majority of the alien species belong to 3 taxa, including Gastropoda (33 species, 13.41% of the

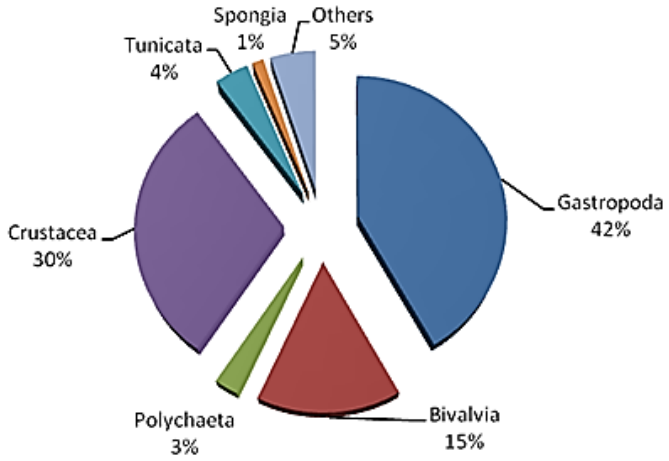

Figure 3. Percentage of alien species for each taxonomic group.

total), Bivalvia (12 species, 9.02%) and Crustacea (24, species 23.76%), followed by Tunicata (3 species 3.79%) and Annelida (2 species, 2.27%) and 5 species other minor taxa (Table 2). Figure 3 shows the percentage of alien species for each main taxonomic group represented by Mollusca (57%) followed by Crustacea (30%), Tunicata (4%) and the rest form (9%).

A total of 53 alien zoobenthic species were already described along the Syrian coast in previous local studies (Ammar, 1995, 2002, 2010, 2014, 2016a, b). Of these, 22 species belong to Mollusca (*Acteocina mucronata*, *Brachidontes pharaonis*, *Cerithium (Thericium) scabridum*, *Chama pacifica*, *Pyrgulina*

Table 1. Updated list of the 79 alien and cryptogenic species zoobenthic found along the Syrian coast.

Species	First record	Habitat	Depth	Abundance	Status	Reference
GASTROPODA						
Diodora ruppellii (Sowerby, 1835)	Lattakia, 1994	Hard bottom, littoral	Littoral - 10 m	common	Established	Ammar (1995)
Smaragdia souverbiana (Montrouzier in Souverbie & Montrouzier, 1863)	Al-Bassit, 2003	Mud-Gravel	5 -35 m	Few	Established	Katsanevakis et al. (2014)
Trochus erithreus Brocchi, 1821	Lattakia, 1992	Hard bottom, Littoral	Littoral	Available	Established	Ammar (1995), Bitar et al. (2003)
Pseudominolia nedyma (Melvill, 1897)	Lattakia Al-Bassit, 2005	Mud-gravel	5-140 m	8-912 ind./m^2	Established	Ibrahim et al. (2005), Arabia (2011), Ammar et al. (2013)
Cerithium scabridum (Philippi,1848)	Lattakia, 1938, 1994	Hard bottom, Littoral, Sand-gravel	< 25 m	Dominant	Established	Pallary (1938)
Rhinoclavis kochi (Philippi, 1848)	Lattakia, 1994	Sandy	< 17 m	Dominant	Established	Ammar (1995)
Finella pupoides Adams A., 1860	Al-Bassit, 2007	Mixed bottom	25-40, 120-140 m	8-432 ind./m2	Established	Arabia (2011), Ammar et al. (2013)
Clathrofenella ferruginea (Adams, 1860)	Al-Bassit, 2007	Mixed bottom	40 m	12-24 ind./m^2	Established	Arabia (2011), Ammar et al. (2013)
Cerithiopsis pulvis (Issel, 1869)	Al-Bassit, Al-Hamedeia, 2007	Mixed bottom	25-40 m	24-40 ind./m2	Established	Arabia (2011)
Cerithiopsis tenthrenois (Melvill, 1896)	Al-Hamedeia, 2007	Mixed bottom	17-25 m	24-56 ind./m^2	Established	Arabia (2011)
Rissoina bertholleti Issel, 1869	Lattakia, 1994	Sand - Gravel	5-12 m	Few	Established	Ammar (1995)
Alvania dorbignyi (Audouin, 1826)	Al-Bassit, Banias and Al-Hamedeia, 2007	Mixed bottom	17-40, 120-160 m	8-368 ind/m^2	Cryptogenic	Arabia (2011), Ammar et al. (2013)
Conomurex persicus (Swainson, 1821)	Lattakia, 1985, 1994	Hard bottom; Soft bottom	Littoral - 70 m	Dominant	Established	Gosselck et al. (1986), Ammar (1995, 2002)
Erosaria turdus (Lamarck, 1810)	Al-Bassit, 2007	Mixed bottom	25, 160 m	8 ind/m^2	Established	Arabia (2011), Ammar et al. (2013)
Sticteulima cf. *lentiginosa* (Adams A., 1861)	Al-Hamedeia, 2007	Detritus	17-25 m	16 ind./m^2	Established	Arabia (2011)
Ergalatax junionae (Houart, 2008)	Al-Bassit, 2004	Hard bottom, littoral	Littoral	Dominant	Established	Ammar (1995, 2002, 2010), Ibrahim et al. (2005)
Indothais lacera (Born, 1778)	Lattakia, 1994	Hard bottom, littoral	Littoral	Few	Established	Ammar (1995)
Murex forskoehlii (Röding, 1798)	Lattakia, 2005	Mud-Sand	>30 m	Few	Established	Katsanevakis et al. (2014)
Fusinus verrucosus (Gmelin, 1791)	Lattakia, 2004	Mud	70 m	Available	Established	Katsanevakis et al. (2014)
Zafra selasphora (Melvill and Standen, 1901)	Al-Bassit and Al-Hamedeia, 2007	Mixed bottom	15-40 m	8-78 ind./m^2	Established	Arabia (2011)
Conus fumigatus Hwass in Bruguière, 1792	Al-Bassit and Tartous, 2007	Mixed bottom	17-40, 120-140 m	32- 64 ind./m^2	Established	Arabia (2011), Ammar et al. (2013)
Pyrgulina maiae Hornung & Mermod, 1924	Lattakia, 1992	Muddy-detritus	5-140 m	8-72	Established	Arabia (2011), Ammar et al. (2013, 2015)
Styloptygma beatrix Melvill, 1910	Ibn-Hani, 2015	Mixed bottom	15-40	Few	Established	**Present study (new records)**
Syrnola cinctella A. Adams, 1860	Ibn-Hani, 2015	Mixed bottom	15-40 m	Few	Established	**Present study (new records)**
Syrnola fasciata (Jickeli, 1882)	Al-Bassit, 2007	Mixed bottom	30, 120-140 m	8-232 ind./m^2	Established	Arabia (2011), Ammar et al. (2013)
Odostomia lorioli (Hornung Mermod, 1924)	Al-Bassit, 2007	Mixed bottom	30-40, 110-160 m	8-72 ind./m^2	Established	Arabia (2011), Ammar et al. (2013)

Table 1. Continued.

Species	First record	Habitat	Depth	Abundance	Status	Reference
Acteocina mucronata (Philippi, 1849)	Al-Bassit and Al-Hadmedia, 2003	Mixed bottom	5, 20-40 m	16-24m	Established	Ibrahim et al. (2005), Arabia (2011)
Ventomnestia girardi (Audouin, 1826)	Ibn-Hani, 2015	Mixed bottom	15-40	Few	Established	**Present study (new records)**
Pyrunculus fourierii (Audouin, 1826)	Al-Bassit and Banias 2007	Mixed bottom	30-40, 120-140 m	8-168 ind./m2	Established	Arabia (2011), Ammar et al. (2013)
Bulla ampulla Linnaeus, 1758	Al-Bassit, 2007	Mixed bottom	40 m	8-16 ind./m2	Established	Arabia (2011)
Thecacera pennigera (Montagu, 1813)	Lattakia, 2013	Muddy	100 m	1 ind.	Cryptogeni	**Present study (new records)**
Aplysia dactylomela (Rang, 1828)	Lattakia, 2013	Rocky	Littoral	2 Specimens	Established	Katsanevakis et al. (2014)
Goniobranchus annulatus (Eliot, 1904)	Tartous, 2018	Rocky	10 m	1 ind.	Established	Ammar and Solaiman (unpublished)
BIVALVIA						
Brachidontes pharaonis (Krauss, 1962)	Lattakia, 1931, 1994	Hard bottom	Littoral - 5 m	Dominant	Established	Gruvel and Moazzo (1931), Ammar (1995)
Septifer cumingii Récluz, 1848	Lattakia, 2015	Sandy	15 m	Dominant	Established	**Present study (new records)**
Crassostrea gigas (Thunberg, 1793)	Lattakia, 1993	Rocky	Littoral	Dominant	Established	Ammar (1995, 2002, 2010), Ibrahim et al.(2005)
Saccostrea cucullata (Born, 1778)	Lattakia, 1993	Hard bottom	Littoral-Sublittoral – 100 m	Dominant	Established	Ammar (1995, 2002, 2010), Ibrahim et al. (2005)
Pinctada imbricata radiata (Leach, 1814)	Lattakia, 1994 (since 1975)	Hard bottom	Littoral-8 m	Dominant	Established	Kinzelbach (1985)
Malleus regula (Forsskål in Niebuhr, 1775)	1931 (collecting place not given)	Hard bottom	5 m	Dominant	Established	Gruvel and Moazzo (1931)
Spondylus spinosus (Schreibers, 1793)	Banias, 1999	Hard bottom	3-15 m	Dominant	Established	Bitar et al. (2003)
Chama pacifica Broderip, 1834	Lattakia, 1993	Hard bottom	Littoral-8 m	Dominant	Established	Bitar et al. (2003)
Afrocardium richardi (Audouin, 1826)	Lattakia, 2009	Soft bottom	15-120 m	8 ind/m^2	Established	Ammar et al. (2013), pressent study
Gafrarium savignyi (Jonas, 1846)	Lattakia, 1993	Rocky and Sand	Littoral -50 m	Dominant	Established	Ammar (1995, 2002), Ammar (2010)
Circenita callipyga (Born, 1778)	Lattakia and Tartous, 2005	Mud	25 m	Rare	Established	Ibrahim et al. (2005)
Paratapes textilis (Gmelin, 1791)	Lattakia, 1992-1993	Shelf bottoms	Offshore	Common	Established	Kucheruk and Basin (1999)
CEPHALOPODA						
Ommastrephase bartramii (Lesueur, 1821)	Ras Al-basset and Jableh, 2016	mud	40-130 m	Common	Established	Ammar and Maaroof (2016c)
CRUSTACEA						
Penaeus pulchricaudatus Stebbing, 1914	Lattakia, 1928	Soft bottom	> 70 m	Dominant	Established	Gruvel (1928)
Metapenaeopsis mogiensis consobrina (Nobili, 1904)	Lattakia, 2012	Muddy	64-100	Single specimen	Established	Ammar et al. (2013)
Metapenaeus Monoceros (Fabricius, 1798)	1980 (collecting place not given)	Soft bottom	>60 m	Abundant	Established	Holthuis (1980), Ammar, (2016b)
Metapenaeus stebbingi Nobili, 1904	Lattakia, 1996	Muddy sand	50-90 m	Rare	Established	Saker and Farah (1994)
Penaeus semisulcatus De Haan, 1844 (in De Haan, 1833-1850)	Lattakia, 1928	Soft bottom	500-600 m	Abundant	Established	Gruvel (1928)
Trachypenaeus curvirostris malaiana Balss, 1933	Banias, 1999	Soft bottom	> 70 m	Rare	Established	Saker and Farah (1994), Hasan et al. (2008)

Table 1. Continued.

Species	First record	Habitat	Depth	Abundance	Status	Reference
Leptochela (Leptochela) aculeocaudata Paul'son, 1875	Banias, 1999	Hard bottom and Soft bottom	10, 14 m	Few	Established	Saker and Farah (1994), Ammar (2002)
Leptochela (Leptochela) pugnax de Man, 1916	Lattakia, 1994	Muddy	110- 160 m	8 ind./m^2	Established	Saker and Farah (1994), Hasan et al. (2008), Ammar et al. (2013)
Alpheus inopinatus Holthuis & Gottlieb, 1958	Lattakia, 2006	In Cystoseira	1 m	Single specimen	Established	Hassan et al. (2008)
Alpheus migrans Lewinsohn & Holthuis, 1978	Lattakia, 2009	Rocky	64-100 m	Single specimen	Established	Ammar et al. (2013)
Saron marmoratus (Olivier, 1811)	Latakia, 2018	Rocky	8-10m	4 individuals	Established	Ammar and Raea (2019)
Ixa monodi Holthuis & Gottlieb, 1956	Lattakia, 1995	Among Macroalgae	2 m	2 Specimens	Established	Hassan et al. (2008)
Coleusia signata (Paul'son, 1875)	Lattakia, 1994	Sand, Mud	Up to 100 m	Rare	Established	Saker (2002), Hasan et al. (2008)
Myra subgranulata Kossman, 1877	Lattakia, 1996	Sand, Mud	14 m, 500 - 600	Dominant	Established	Saker and Farah (1994), Hassan et al. (2008), Ammar et al. (2013), Ammar (2016b)
Micippa thalia (Herbst, 1803)	Lattakia, 1993	Hard bottom	2 m	One specimen	Established	Hassan et al. (2008)
Ashtoret lunaris (Forskål, 1775)	Latakia, 2017	sand	littoral	2 specimen	Established	Ammar and Arabia (2018)
Charybdis (Charybdis) hellerii (A. Milne-Edwards, 1867)	Lattakia, 1992	Soft bottom	5 - >70 m	Abundant	Established	Kuznetsov et al. (1993), Saker and Farah (1994, 1997), Saker (2002), Ibrahim et al. (2005), Hassan et al. (2008), Ammar (2010)
Charybdis (Goniohellenus) longicollis Leene, 1938	Lattakia, 2003	Soft Bottom	69-100, 500-600 m	Dominant	Established	Ibrahim et al. (2005), Ammar et al. (2013), Ammar (2016b)
Portunus (Portunus) segnis (Forskål, 1775)	Lattakia, 1930	Soft bottom	5-70 m	Dominant	Established	Gruvel, 1928), Monod 1931), Saker and Farah (1994), Ammar (2002), Ibrahim et al. (2005) Hassan et al. (2008) Ammar et al. (2013), Ammar (2016b)
Thalamita poissonii (Audouin, 1826)	Lattakia, 2005	Soft bottom	50 - 60 m	Rare	Established	Ibrahim et al. (2005), Hasan et al. (2008)
Glabropilumnus laevis (Dana, 1852)	Banias, 1996, 2002	Hard bottom and Soft bottom	10, 14 m	Few	Established	Ammar (2002), Hassan et al. (2008)
Atergatis roseus (Rüppell, 1830)	Lattakia, 2002	Rocky - sandy	Infralittoral	Abundant	Established	Saker (2002), Ammar (2010)
Macrophthalmus (*Macrophthalmus) indicus* Davie, 2012	Lattakia, 2003	Hard bottom	13-120 m	24 ind./m^2	Established	Bitar et al. (2003), Brahim, et al. (2005), Ammar et al. (2013)
Erugosquilla massavensis (Kossmann, 1880)	Banias, 2002	Mud	> 70 m	Abundant	Established	Ammar (1995), Hassan et al. (2008)
TUNICATA						
Phallusia nigra Savigny, 1816	Banias, 1999	Hard bottom	Littoral	Dominant	Established	Bitar et al. (2003)
Herdmania momus (Savigny, 1816)	Ibn Hani, 2002	Rocky	26-31 m	Dominant	Established	Bitar et al. (2003)
Ascidiella aspersa (Müller, 1776)	HIMR, 1993	Rocky	littoral	Dominant	Established	**Present study (new records)**
ANNELIDA						
Spirobranchus tetraceros (Schmarda, 1861)	Al Bassit, 2007	sandy-muddy	40-50 m	8-16 ind./m^2	Established	Bitar et al. (2003), Ammar et al. (2011)
Spirorbis (Spirorbis) marioni Caullery, Mesnil, 1897	Lattakia, 1995	Rocky	Littoral	Dominant	Established	Ammar, 1995), Zibrowius and Bitar (2003)

Table 1. Continued.

Species	First record	Habitat	Depth	Abundance	Status	Reference
ECHINODERMATA						
Ophiactis macrolepidota Marktanner-Turneretscher, 1887	Lattakia, 2003	Rocky	7-11 m	Few	Established	Zibrowius and Bitar (2003)
Synaptula reciprocans (Forsskål, 1775)	Ras Samra, Ibn-Hani, 2003	*Cymodocea nodosa* meadow	12-32 m	Few	Established	Bitar et al. (2003)
CNIDARIA						
Macrorhynchia philippina Kirchenpauer, 1872	North of Lattakia, 1999,	Rocky	7m	Few	Established	Zibrowius and Bitar (2003)
SPONGIA						
Agelas linnaei (de Voogd *et al*. 2008)	Latakia, 2014	Rocky	15-30 m	One specimen	Established	Ammar and Fadel (2017)

Table 2. Number and percentage composition of native and alien species along the Syrian coast.

	Total number of species	Native species	Alien and cryptogenic species	Percentage of alien species on the total
Gastropoda	246	213	33	13.41
Bivalvia	133	121	12	9.02
Polychaeta	88	86	2	2.27
Crustacea	101	77	24	23.76
Spongia	29	28	1	3.45
Others	87	82	7	8.04
Total	684	607	79	11.55

maiae, *Diodora ruppellii, Ergalatax junionae*, *Fusinus verrucosus*, *Gafrarium savignyi* , *Malleus (Malvufundus) regulus*, *Paratapes textilis, Pinctada imbricate radiata*, *Pseudominolia nedyma*, *Rhinoclavis kochi*, *Rissoina bertholleti*, *Saccostrea cucullata, Smaragdia souverbiana, Spondylus spinosus*, *Conomurex persicus*, *Indothais lacera* and *Trochus erithreus*) and 24 species belong to crustacean (*Alpheus inopinatus*, *A. migrans*, *Atergatis roseus*, *Balanus trigonus*, *Charybdis (Charybdis) hellerii*, *C. (Goniohellenus) longicollis*, *Erugosquilla massavensis*, *Heteropanope laevis*, *Ixa monodi*, *Leptochela aculeocaudata*, *L. pugnax*, *Coleusia signata* , *Macrophthalmus graffei*, *Penaeus pulchricaudatus*, *P. semisulcatus*, *Metapenaeopsis mogiensis consobrina*, *Metapenaeus monoceros*, *M. stebbingi*, *Micippa thalia* var*. caledonica*, *Myra subgranulata, Portunus (Portunus) segnis, Thalamita indistincta*, *T. poissonii* and *Trachysalambria palaestinensis*. Other species already reported include two species of Echinodermata (*Ophiactis parva* and *Synaptula reciprocans*), two species of Annelida (*Spirobranchus tetraceros* and *Spirorbis marioni*), one species of cnidaria (*Macrorhynchia philippina*) and two species of chordate (*Herdmania momus* and *Phallusia nigra*).

Other species known as aliens in the Mediterranean were already described in local studies on the Syrian coast, but not reported in the international database as present in Syria. These include 13 species of gastropoda collected during the period 2007-2014 from different sites, including *Alvania dorbignyi*, *Bulla ampulla*, *Cerithiopsis pulvis*, *C. tenthrenois*, *Clathrofenella ferruginea*, *Conus fumigatus*, *Erosaria turdus*, *Finella pupoides*, *Odostomia lorioli*, *Pyrunculus fourierii*, *Sticteulima* cf. *lentiginosa*, *Syrnola fasciata* and *Zafra selasphora* (Arabia, 2011; Ammar, 2016a). Furthermore, 2 species of bivalvia viz. *Afrocardium richardi* and *Circenita callipyga* were reported (Ammar, 2002; Ibrahim et al., 2005; Ammar et al., 2013). As research continued, one species of cephalopods i.e. the flying squids, *Ommastrephase bartramii* (Lesueur, 1821) has recorded for the first time locally, three individuals

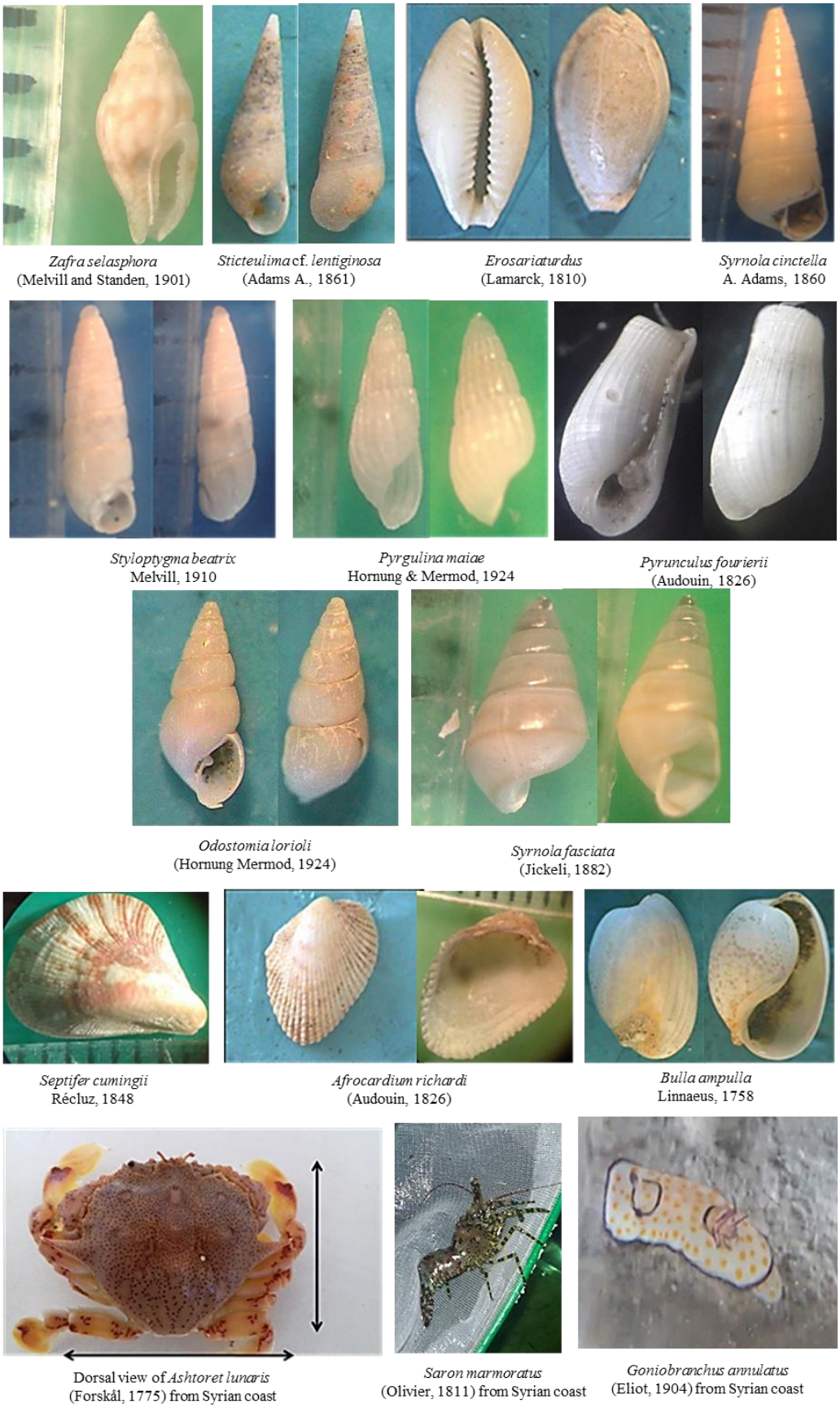

Figure 4. New recorded alien species of the Syrian coastal water.

were collected in March and April 2016, two individuals from the Ras Al-basset coast and one from the Jableh coast, at depths ranging from 40-130 m (Ammar and Maaroof, 2016). In addition, one species of sea slugs, *Goniobranchus annulatus* (Eliot, 1904) has recently collected (in October 2018) from Tartous in the south of Syria. This Lessepsian migrant was invaded the Mediterranean Sea, and recorded since 2007 (Daskos and Zenetos, 2007).

New recorded alien crustaceans are four individuals of *Saron marmoratus* (Olivier, 1811) collected from the rocky bottom near Lattakia Port in 2018, (Ammar and Raya, 2019) and two individuals of *Ashtoret lunaris* (Forskål, 1775) from the sandy beach in south of Latakia in 2017 (Ammar and Arabia, 2018), seven individuals of *Metapenaeopsis aegyptia* (Galil and Golani, 1990) from the depth of 60 m in 2012 from the Latakia coast (Ammar, 2016). Furthermore, new record of exotic species of demospongia *Agelas linnaei* (de Voogd et al., 2008) was reported for the first time in the Syrian coast from sublittoral area at 15-30 m of Ibn Hani region in April-May 2014. This species is Indo-pacific origin (Ammar and Fadel, 2017).

The present study also reports new records of alien species in the marine protected area of Ibn Hani, north of Lattakia, at depths ranging between 1-40 m, collected during 2015-2016. These include two species of gastropoda, including *S. cinctella* and *Ventomnestia girardi*, and one species of bivalvia, *Septifer cumingii* (Table 1). These species are Indo-Pacific origin, introduced to the Mediterranean Sea via the Suez Canal (Zenetos et al., 2004).

Trends and distribution: The increase in the number of alien species in the Syrian waters is due to the continuing introduction of new species from the Red Sea and neighboring areas as well as the increase in research effort which is conducted in new areas and depths.

Regarding Mollusca, 31% of the total number of individuals are found in the soft bottom at depth 90-160 m (Ammar et al., 2013). In the littoral region, the invasive species of *B. pharaonis*, *E. junionae*, *T. erithareus* and *C. scabridum* are dominate in the coastal region, where they have been found for more than twenty years, similar to *B. pharaonis* (Saker and Ammar, 1994b) and *C. scabridum* and *E. junionae* (Saker and Ammar, 1994a). On the hard bottom of the sublittoral zone, the most important alien species in terms of distribution and abundance are *P. nedyma*, *C. scabridum*, *F. pupoides*, *S. fasciata*, *R. kochi*, *C. persicus* (gastropoda), and *B. pharaonis*, *G. savignyi* (Jonas, 1846), *P. imbricata radiata*, *M. regula*, *C. pacifica* and *S. spinosus* (bivalves). In the soft bottom, *Septifer forskali* is dominant at depth 15-40 m and *S. cucullata* attached to *S. tetraceros* at depth of 60 m. All new alien species are of Indo-Pacific and/or Red Sea origin, introduced to the Mediterranean via the Suez Canal. The majority of new alien gastropods are still spreading in few numbers, which did not exceed 56 individual/m^2 in the benthic habitats at the littoral and sublittoral zone, lower than a depth of 160 m. Many other species known as invasive are dominant or common in the littoral and/or sublittoral habitats such as *C. scabridum*, and *R. kochi*. *Conomurex persicus*, *E. junionae*, *D. ruipplli* and *T. erithraeus*. *Rhinoclavis kochi*, *C. scabridum*, and *Murex forskoehli* were found at deep Syrian water, although both *R. kochi* and *C. scabridum* are the most important invasive species in the shallow area. Abundance of *G. savignyi* is increasing and *Ruditapes decussatus* appears at deeper sites.

Concerning crustacean, 90 species known from different areas and found between 1992 and 2016 (Saker and Farah, 1994, 1997; Ammar, 2002; Arabia, 2011; Hassan et al., 2008; Ammar, et al., 2013). 24 species are Indo-Pacific origin (23.76%). Most of these species are brawns, lobsters and crabs that economically important. Lessepsian migrant shrimps, *P. pulchricaudatus* and *P. semisulcatus* are commercially important and more abundant at the depth (50-100 m) on the muddy and sandy bottoms As well as presence of *M. monoceros* in the same medium. *Portunus* segnis is common at depths of 50-70 m. *Erugsquilla massawenses* (migrant lobster) is found at a depth over 50 m. Two crab species viz. *M. subgranulatais* and *C. helleri* are dominant on

muddy bottom at depth of >50 m. *Leptochela aculeocaudata* and *Glabropilumnus laevis* are found on the rocky bottom in sea grass habitats. Recent studies showed occurrence of two species of crabs, *M. subgranulata* and *C. longicollis* in the muddy bottom at depth of 500-600 m (Ammar, 2016). The number of alien crabs on the Syrian coast, which is 14, does not seem to be significant in comparison to total number of exotic crabs recorded in the Mediterranean Sea that reported to be 39 until 2013 (Zaouali et al., 2012; Karhan et al., 2013).

Two cryptogenic alien species viz. *Thecacera pennigera* and *A. d'orbigny* are found in 2013 from a muddy bottom at depth of 100 m and in 2011 at depths ranged 17-160 m in the mixed bottom, respectively. Concerning Annelida, the total number is 89 species (Ammar 1995, 2002; Ammar et al., 2011) that two alien species reported in previous studies (Ammar, 1995; Bitar, 2003), *S.* (*Spirorbis*) *marioni* being dominant on the rocky substrate in the littoral zone and *S. tetraceros* is found in the soft bottoms in the sublittoral zone.

In conclusion, the expansion of alien species in the Syrian coast could be explained in the different behaviour or dynamic of these species with time (van Aartsen, 2006) and their ability to tolerate the disturbances in the marine environment (Çinar et al.,2006; Occhipinti-Ambrogi and Savini, 2003), especially regarding the increase in water temperature in deep sea associated with climate changes, with a sharp change in the hydrological characteristics of the Eastern basin (Lejeusne et al., 2010; Raitsos et al., 2010; Lelieveld et al., 2012). Many alien species were found at depth >100 m, few were dominant, this observations refer to expand some of alien species from the shallow water to the deep sea some of them dominating since more than 20 years.

Establishment success of invasive species: Most of 79 reported alien species found along the Syrian coast are established, none of them is questionable, casual or cryptogenic (Table 1). Some of them are dominant in the marine habitats and compete with native species for food and habitat. These include *C. scabridum*, *P. maiae*, *F. pupoides*, *R. kochi*, *C. persicus*, *P. textilis*. Eleven species are listed in the black list of marine invasive species and some of these species are harmful since they affect local species or biodiversity, especially *F. pupoides*, *R. kochi*, *C. persicus*, *C. pacifica*, *S. tetraceros*, *L. pugnax* and *C. longicollis*. In addition, species such as *P. imbricata radiata*, *Crassostrea gigas* and *S. cucullata* have a negative impact on the fish resources and environmental health as well as on underwater constructions in sublittoral zone. *Chama pacifica* and *S. spinosus* replaced the two native species *C. phoides* and *S. gaederopus*. The pharaonic mussel *B. pharaonis* displaced the native mytilid, *Mytilaster minimus* completely, with a great impact on the local benthic populations. *Cerithium scabridum* has replaced *C. vulgatum*, and *C. rupestra*. *C. persicus*, *A. drobigni* and *C. kochi* are present in high density and biomass. The economic impact of the most of invasive species in Syria is little explored. Some of them, such as *C. pacifica* and *S. spinosus*, are valuable species for seashell collectors or embellishment with a small trading market. *Pinctada imbricate radiata* is sold for food in the markets and restaurants *P. pulchricaudatus, P. semesolcatus* and *M. monocerus* are also commercially important and valuable in the market.

The number of invasive species increases with the number of species entering the eastern Mediterranean. According to Zenetos (2010, 2012), presently, more than 30 species of zoobenthos have been described as invasive species in the Syrian coast. It is also noticeable the spread of some invasive species into deeper areas. Many species of crustacean viz. *P. pulchricaudatus* and *P. semisulcatus* are abundant along the Syrian coast in the sublittoral area down to depth 100 m. In addition, *M. monoceros*, *M. stebbingi*, *P. segnis* and *E. massavensis* are also abundant. The negative impact of alien species in the Mediterranean Sea is documented in many works (Occhipinti-Ambrogi, 2000; Streftaris and Zenetos, 2006; EEA, 2012). Success of the most established alien zoobenthic species in Syrian coast can be explained with the hydrological characteristics of Syrian marine waters, showing an increase in salinity higher than 39 PSU, and a temperature ranging 13-32°C. Taking in

consideration that all of alien species are thermophilic species, the Syrian marine environment confirm to be a favorite environment to establish these alien species.

Comparison with neighbouring countries: A comparison of the total number of alien species of zoobenthos in Syria with those of some neighbouring countries of the Eastern Mediterranean revealed a relatively low number of the recorded species. A total of 239 marine NIS and cryptogenic species are reported from Greece (Zenetos et al., 2015b), most of them i.e. 214 species are aliens and 62 cryptogenic (Zenetos et al., 2018). Out of these, 146 are zoobenthos as follows: one Porifera, two Ctenophora, one Platyhelminthes, five Cnidaria, 44 Mollusca, 35 Annelida, eight Bryozoa, 42 Crustacea, and three Echinodermata and seven Tunicata (see http://elnais.hcmr.gr/elnaisdatabase-2), while the rest are plants, Foraminifera and fishes, etc.. In Italy, 35 alien molluscan species recorded (Crocetta et al., 2013a). In Turkey, a total of 111 molluscan species (Öztürk et al., 2014), including six Echinodermata (Öztoprak et al., 2014) from the Levantine coast, 50 crustacean (Suat Ate et al., 2013), and 57 Polychaeta have been reported (Çinar et al., 2014). A recent study revealed that the contribution of alien Mollusca account for approximately 30% of the molluscan fauna i.e. 32 out of 106 (Guarnieri et al., 2017). In Cyprus 42 species of Mollusca, 19 Polychaeta, 12 crustacean, and 10 species from other taxa have been reported up to July 2009 (Katsanevakis et al., 2009). The updated checklist of Mollusca of Lebanon is 32 species, including 13 opisthobranches (12 alien and one cryptogenic) (Crocetta et al., 2013b) and 18 Bivalvia (Crocetta et al., 2013c).

Conclusion

The present study indicate that the benthic fauna along the Syrian coast has suffered from an increase in the number of alien species, with the record of new species, their extension in the northern part of the Syrian coast and disappearance of many native species. Alien species consist 11.55% of the total number of species of zoobenthos, with dominance of Mollusca and Crustacea. Many of the established species have become an invader and dominant in the marine environment of Syria. Their proliferation is accelerating and also their negative impact on the native species on the socio-economic activities seems to be clear.

What is required today of the concerned scientific community is increasing the effort to monitor the environmental situation in the Syrian coast and help to predict future changes and find ways to address them or managed. Rapid assessment surveys are one approach to quickly characterize the native, non-native and cryptogenic species present in the Syrian marine environment. The study of the relation between native and alien species will be the aims of our future research based on the knowledge gathered in the present study.

Acknowledgements

I would like to thank everyone who helped get the samples and I am grateful to S. Eagderi the managing editor of IJAB who comments substantially improved the quality of the manuscript. Sincere thanks to A. Zenetos and P. Magni for commenting on the article.

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