

# An updated overview of the marine alien and cryptogenic species from the Egadi Islands Marine Protected Area (Italy)

Anna Maria Mannino<sup>1</sup> · Manfredi Parasporo<sup>2</sup> · Fabio Crocetta<sup>3</sup> · Paolo Balistreri<sup>1</sup>

Received: 26 December 2015 / Revised: 6 April 2016 / Accepted: 12 April 2016 / Published online: 14 May 2016  
© Senckenberg Gesellschaft für Naturforschung and Springer-Verlag Berlin Heidelberg 2016

**Abstract** An updated overview of the marine alien and cryptogenic species recorded in the Egadi Islands Marine Protected Area (Tyrrhenian Sea, Italy), based on relevant publications, grey literature and unpublished data, is presented and discussed. Altogether, 17 species (14 aliens and 3 cryptogenic) belonging to five taxa are present in the area: Rhodophyta (*Antithamnionella elegans*, *Asparagopsis armata*, *Asparagopsis taxiformis*, *Bonnemaisonia hamifera*, *Botryocladia madagascariensis*, *Ceramium strobiliforme*, *Laurencia caduciramulosa*, *Lophocladia lallemandii*, *Neosiphonia harveyi*, *Womersleyella setacea*), Chlorophyta (*Caulerpa cylindracea* and *Caulerpa taxifolia*), Mollusca (*Aplysia dactylomela*), Arthropoda (*Percnon gibbesi*) and Cordata (*Fistularia commersonii*, *Kyphosus vaigiensis* and *Stephanolepis diaspros*). The overall Mediterranean presence of one further taxon recorded from the area, *Zygochlamys patagonica* (Mollusca), is here confuted since recent findings of living specimens with certain data are missing. One loose valve of “*Pinctada imbricata radiata* (Mollusca)” was found in 2010 at Favignana, but we did not include it in the list of alien species, pending further finding of living or dead specimens. Unpublished distributional data are reported for some

of these species, and their known distribution in the Aegadian Archipelago is mapped. Records of *P. gibbesi* (a conspicuous number of specimens) constitute the first for the archipelago. All the species included in the present paper were recorded after the Egadi Islands Marine Protected Area was established, with the first record dating back to 2000. This is presumably due to the recent increase in research programs on marine reserves. Finally, we provide the establishment status of all the recorded species updated to 2015, and discuss why unaided spread (whether alien or native) and/or transport-stowaway constitute the more plausible vectors of introduction.

**Keywords** Egadi Islands Marine Protected Area · Italy · Mediterranean Sea · Review · Marine alien and cryptogenic species

## Introduction

Alien species are presently considered one of the most serious threats, after habitat destruction, to biodiversity and natural ecosystem functioning (Bax et al. 2003; Wallentinus and Nyberg 2007). Marine alien species may become invasive and have significant effects on the environment (biodiversity loss, habitat modifications and alterations in community structure), economy and human health (Galil 2007; Katsanevakis et al. 2014), raising serious concerns in the scientific community.

The Mediterranean Sea is an important hotspot of marine biodiversity, also for alien species, and it is one of the major areas severely affected by marine invasions, in terms of both the number of species and the rate of introduction (Coll et al. 2010; Lejeune et al. 2010; Zenetos et al. 2012; Galil et al. 2015). The number of marine alien species reported so far ranges from more than 600 to

---

Communicated by P. Martinez Arbizu

✉ Anna Maria Mannino  
annamaria.mannino@unipa.it

<sup>1</sup> Department of Biological, Chemical and Pharmaceutical Sciences and Technologies, Section of Botany and Plant Ecology, University of Palermo, Via Archirafi 38, 90123 Palermo, Italy

<sup>2</sup> Strada Provinciale Punta Marsala 73, 91023 Favignana, Italy

<sup>3</sup> Hellenic Centre for Marine Research, Institute of Marine Biological Resources and Inland Waters, GR-19013 Anavyssos, Greece

nearly 1.000 (Zenetos et al. 2012; Galil and Goren 2014). The reported discrepancies in numbers are mostly due to difficulties in objectively assessing whether the spread of taxa is due to natural dispersal or to human activities. A conspicuous increase in the rate of introduction of marine alien species has been noticed during recent decades (Zenetos et al. 2010; Occhipinti-Ambrogi et al. 2011a, b; Katsanevakis et al. 2013), due to escape from confinement, transport-stowaway and corridor (Suez Canal) entries (categories according to the Convention on Biological Diversity: CBD 2014). Within the Mediterranean Sea, a relatively high number of marine alien species occur around the Italian peninsula (Occhipinti-Ambrogi et al. 2011a, b), and, in particular, Sicily and its surrounding islands are characterized by intense maritime traffic, including that related to fisheries and recreation (Occhipinti-Ambrogi et al. 2011a, b; Katsanevakis et al. 2014). These and other human activities fostering the introduction of marine alien species, have made the region vulnerable and susceptible to biological invasions (Bianchi 2007; Occhipinti-Ambrogi et al. 2011a, b; Katsanevakis et al. 2012), despite the high number of Marine Protected Areas (MPAs) already established. Even though MPAs have a strong potential for habitat and biodiversity conservation, they seem to be ineffective in protecting from biological invasions, and in some cases may enhance them (e.g. Byers 2005; Klinger et al. 2006; Burfeind et al. 2013). In fact, high numbers of visitors, increasing disturbance, vectors (e.g. boat anchors, SCUBA equipment, bilge water, hull fouling) and subsequent dispersal of propagules (Minchinton and Bertness 2003; West et al. 2007; Britton-Simmons and Abbott 2008; Burfeind et al. 2013) could promote the introduction of invasive species.

Since reliable and accessible information (inventories, databases, literature) on distribution and status, introduction vectors and impacts of marine alien species is crucial for planning effective management and conservation strategies, the aim of the present paper is to offer an updated overview on the marine alien and cryptogenic species from the Egadi Islands MPA (Aegadian archipelago, Tyrrhenian Sea, Italy), especially in order to provide a baseline report of the situation up to 2015, necessary for planning future research and activities within the MPA.

## Materials and methods

### Description of the area

The Egadi Islands MPA, the largest Italian MPA which was instituted in 1991, is a small archipelago located approximately 7–9 km from the western coast of Sicily (Italy, Tyrrhenian Sea). It is composed of three main islands (Favignana,

Marettimo and Levanzo) and a few small islets (Galeotta, Galera, Preveto, Formica and Maraone) (Fig. 1).

### Literature research and unpublished data

All the relevant publications and reports dealing with marine alien and cryptogenic species in the Egadi Islands MPA were searched and analysed. Unpublished data provided by the authors of the present paper were included, as well as personal communications provided by skilled citizen scientists. Sites of occurrence of marine alien and cryptogenic species are listed in Table 1, while detailed information on the records is reported in Table 2.

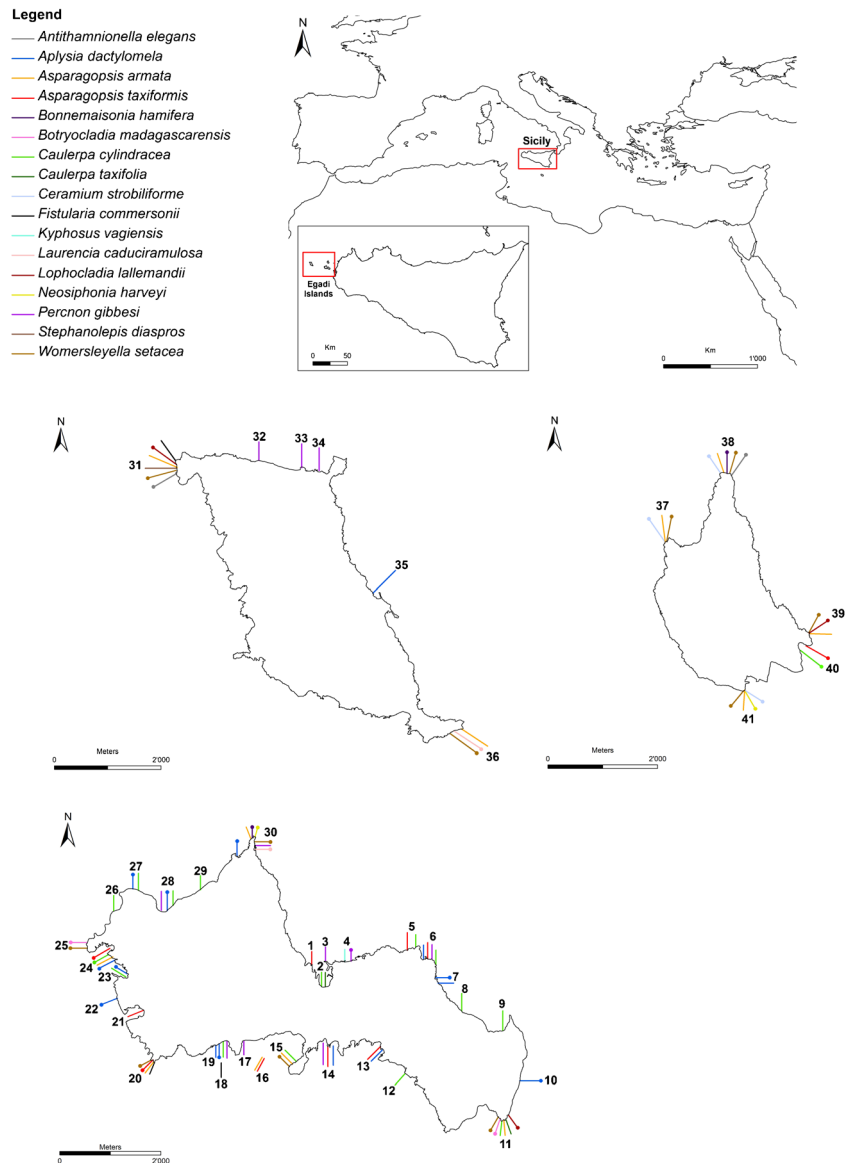
Three main mechanisms of introduction are recognized by the CBD (2014): importation of a commodity, arrival via a transport vector, or spread from a neighbouring region. The most plausible pathways of introduction in the Egadi Islands MPA were attributed according to the hierarchical pathway classification adopted by the CBD (2014). In particular, the following two categories were considered: (1) the transport-stowaway (S-T), which mostly “refers to the moving of live organisms attached to transporting vessels and associated equipment and media”, and (2) the unaided spread (US), which refers to the secondary dispersal of alien species from neighboring areas. However, since in our list we have also retained species which may turn out to be vagrants and not truly aliens, we have used this term cautiously, since unaided spread may possibly be nothing more than natural spread.

The establishment success of each species was determined on the basis of published and unpublished data. We considered species as casual (C) (here synonymous with non-established) when recorded only once on the basis of one or very few specimens, and as established (E) when the species was either established in the wild with free-living, self-maintaining and self-perpetuating populations, or recorded at least twice and spread over time and space.

### Alien species definition

The definition of alien species (non-native, non-indigenous, exotic) used here follows the European Commission (EC 2008): “a species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce”. However, some species recently recorded from the Mediterranean cannot be described with certainty as native (therefore including vagrant, according to the EC definition of “alien species”) or alien, and may be cryptogenic (see Carlton 1996: a species that cannot be included with confidence among native nor among introduced ones).

**Fig. 1** Known sites of occurrence of marine alien and cryptogenic species in the Egadi Islands MPA (Italy). Numbers as in Tables 1 and 2. Published distributional data are reported as *single lines*, whilst unpublished data are reported as *lines ending in a circle*



So far, this term has been mostly used in defining circumtropical species or species with a disjoint distribution, and whose native range is still unknown or whose presence may be the result of past introductions not recorded in the literature (Carlton 2009). This term has also been applied to small, cryptic species that may have gone unnoticed for hundreds of years. In contrast, in some cases (e.g. large and/or obvious shallow water species), we are dealing with taxa clearly recorded for the Mediterranean relatively recently, excluding the possibility that their historical presence in the Mediterranean may have gone unnoticed, and whose vector of arrival in the Mediterranean is still unknown and may be due to natural spread or human activities. We also considered

these species as “cryptogenic”, pending the possibility to include or exclude them from alien lists in the future.

**Results and discussion**

Altogether, 14 alien and 3 cryptogenic species have been recorded from the Egadi Islands MPA (some of them are shown in Fig. 2). Ten are Rhodophyta, two are Chlorophyta, one Mollusca, one Crustacea and three are Pisces. Another species reported from Favignana, *Zygochlamys patagonica* (King, 1832) [Repetto (1989) as *Chlamys lischkei* (Dunker, 1850)], was excluded. This species is still reported in some

**Table 1** Known sites of occurrence of marine alien and cryptogenic taxa from the Egadi Islands MPA (Italy); numbers as in Table 2 and Fig. 1

Island	Sites of occurrence
Favignana	<b>1</b> Arreturino (37.93302°N, 12.32159°E); <b>2</b> Praia (37.93012°N, 12.32585°E); <b>3</b> Scalo San Leonardo (37.93330°N, 12.32050°E); <b>4</b> Lungomare (37.93401°N, 12.32967°E); <b>5</b> Cala Graziosa (37.93661°N, 12.34486°E); <b>6</b> Scalo San Nicola (37.93465°N, 12.34757°E); <b>7</b> Scalo Cavallo (37.93170°N, 12.34955°E); <b>8</b> Zona Torretta (37.92551°N, 12.35565°E); <b>9</b> Cala Rossa (37.92228°N, 12.36498°E); <b>10</b> Bue Marino (37.91344°N, 12.36910°E); <b>11</b> Punta Marsala (37.91527°N, 12.36638°E); <b>12</b> Grotta Perciata (37.91412°N, 12.34340°E); <b>13</b> Lido Burrone (37.91844°N, 12.33766°E); <b>14</b> Cala Monaci (37.91866°N, 12.32589°E); <b>15</b> Punta Longa (37.91638°N, 12.30277°E); <b>16</b> Scoglio Palumbo (37.91444°N, 12.28944°E); <b>17</b> Cala del Passo (37.91890°N, 12.30640°E); <b>18</b> Preveto (37.91890°N, 12.30202°E); <b>19</b> Pirreca (37.91791°N, 12.30085°E); <b>20</b> Scoglio Corrente (37.95611°N, 12.30055°E); <b>21</b> Cala Rotonda (37.92411°N, 12.28406°E); <b>22</b> Chiarito (37.92600°N, 12.27821°E); <b>23</b> Cala Grande (37.93290°N, 12.27759°E); <b>24</b> Pozzo Ponente (37.93306°N, 12.27761°E); <b>25</b> Punta Sottile (37.93409°N, 12.27245°E); <b>26</b> Sicchitedda (37.94153°N, 12.27670°E); <b>27</b> Punta Ferro (37.94536°N, 12.28214°E); <b>28</b> Pozzo dell'Alga (37.94170°N, 12.288100°E); <b>29</b> Pozzo (37.94580°N, 12.29607°E); <b>30</b> Faraglione (37.95555°N, 12.31388°E).
Marettimo	<b>31</b> Punta Mugnone (37.99972°N, 12.03305°E); <b>32</b> Punta due Frati (37.99166°N, 12.04638°E); <b>33</b> Libano (37.99111°N, 12.05527°E); <b>34</b> Scalo Maestro (37.99000°N, 12.05777°E); <b>35</b> Scalo Vecchio (37.96936°N, 12.07261°E); <b>36</b> Punta Bassana (37.94472°N, 12.08305°E).
Levanzo	<b>37</b> Punta dei Sorci (38.01638°N, 12.32222°E); <b>38</b> Capo Grosso (38.02638°N, 12.33888°E); <b>39</b> Punta Altarella (37.99972°N, 12.35833°E); <b>40</b> Cala Minnola (37.99219°N, 12.35312°E); <b>41</b> Il Faraglione (37.99083°N, 12.33305°E).

Mediterranean lists (e.g. Zenetos et al. 2004, 2010; Templado and Villanueva in Coll et al. 2010; Galil et al. 2016) due to three Mediterranean records (Gubbioli and Nofroni 1985; Repetto 1989; Crocetta and Renda 2008). However, since we are not sure if all Mediterranean records are based on discards in the field of dead specimens imported with shrimps (some presumably even with soft parts), or that specimens obtained “from fishermen” may refer to trawlings from the Atlantic by fleets based only in the Mediterranean Sea, we suggest the exclusion of this taxon from all Mediterranean lists until confirmed by recent findings of living specimens with certain distributional data. One loose valve of “*Pinctada imbricata radiata* (Leach, 1814)”, according to major databases (e.g. Bouchet 2015), was first found in the Egadi Islands MPA in 2010 at Favignana (P. Balistreri, unpublished data). We cannot say with certainty if the specimen lived where it was found, or if it was discarded in the area. Therefore, we did not include it in the list of alien species, pending further findings of living or dead specimens.

All records come from the three main islands only; there are no records from the small islets, presumably due to their limited coastlines and the few field studies carried out in these areas. The known distribution of the taxa included in the present review is reported in Table 2 and shown in Fig. 1 (see Table 1 for the site codes). Among them, the occurrence of *Percnon gibbesi* (H. Milne Edwards, 1853) constitutes the first confirmed record from the Egadi Islands MPA. The most plausible vectors of arrival in the Egadi Islands MPA and local establishment success are reported in Table 2.

*Antithamnionella elegans* (Berthold) J.H. Price & D.M. John, 1986

#### Status: ALIEN SPECIES

**Remarks:** first reported from the Mediterranean Sea prior to 1882 in the Gulf of Naples (Berthold 1882) as *Antithamnion elegans* Berthold, 1882. Transport-stowaway is considered the plausible pathway of introduction in the Mediterranean Sea.

**Presence in the Egadi Islands MPA:** first reported from the Egadi Islands MPA in 2001 at Levanzo (40 m depth) and Marettimo (0, 1 m depth) (Catra et al. 2006). There are no further records of this species in the area. Both unaided spread or transport-stowaway may be considered plausible pathways of introduction for local specimens.

*Asparagopsis armata* Harvey, 1855 complex (Fig. 2a)

#### Status: ALIEN SPECIES

**Remarks:** originally described from western Australia, specimens from several biogeographic areas morphologically ascribed to *Asparagopsis armata* Harvey, 1855 belong to a complex of cryptic species (see Dijoux et al. 2014), and therefore we report them as “*Asparagopsis armata* Harvey, 1855 complex”. According to Dijoux et al. (2014), *A. armata* specimens from Europe fall within the same clade as South African and Tanzanian specimens, while another newly discovered clade is restricted to western Australia, Tasmania and New Zealand. Specimens belonging to this complex of species were first reported in the Mediterranean Sea in 1923, from the Algerian coast (Feldman and Feldman 1942), and their alien status in the Mediterranean area has been confirmed by the molecular studies of Andreakis et al. (2004, 2007).

**Presence in the Egadi Islands MPA:** the first report of specimens belonging to this complex of species from the

**Table 2** Marine alien and cryptogenic taxa from the Egadi Islands MPA (Italy); see Table 1 for the site codes

Status, taxon and known sites of occurrence	Year	Plausible vectors	Establishment
A: <i>Antithamnionella elegans</i> (Berthold) J.H. Price & D.M. John, 1986			
M: 31	2001	US/T-S	C
L: 38	2001	US/T-S	C
A: <i>Asparagopsis armata</i> Harvey, 1855 complex			
F: 11; 15; 16; 20; 23; 24; 30	2001	US/T-S	E
M: 31; 36	2001	US/T-S	E
L: 36; 37; 38; 40	2001	US/T-S	E
A - <i>Asparagopsis taxiformis</i> (Delile) Trevisan de Saint-Léon, 1845 complex			
F: 1; 5; 6; 13; 14; 16; 20; 21; 23	2000	US/T-S	E
L: 40	2015	US/T-S	C
A: <i>Bonnemaisonia hamifera</i> Hariot, 1891			
F: 30	2001	US/T-S	C
L: 38	2001	US/T-S	C
A: <i>Botryocladia madagascariensis</i> G. Feldmann, 1945			
F: 11; 25	2001	US/T-S	E
A: <i>Caulerpa cylindracea</i> Sonder, 1845			
F: 2; 5; 6; 8; 9; 11; 12; 15; 18; 23; 24; 26; 27; 29	2003	US/T-S	E
L: 40	2004	US/T-S	C
A: <i>Caulerpa taxifolia</i> (M. Vahl) C. Agardh, 1817			
F: 2; 11	2004	US/T-S	E
A: <i>Ceramium strobiliforme</i> G.W. Lawson & D.M. John, 1982			
L: 37; 38; 41	2001	US/T-S	E
A: <i>Laurencia caduciramulosa</i> Masuda & Kawaguchi, 1997			
F: 30	2001	US/T-S	C
M: 36	2001	US/T-S	C
A: <i>Lophocladia lallemandii</i> (Montagne) F. Schmitz, 1893			
F: 11	2001	US/T-S	C
L: 38; 39	2001	US/T-S	E
M: 31	2001	US/T-S	C
A: <i>Neosiphonia harveyi</i> (J.W. Bailey) M.S. Kim, H.G. Choi, Guiry & G.W. Saunders, 2001			
F: 30	2001	US/T-S	C
L: 41	2001	US/T-S	C
A: <i>Womersleyella setacea</i> (Hollenberg) R.E. Norris, 1992			
F: 11; 15; 20; 25; 30	2001	US/T-S	E
L: 37; 38; 39; 41	2001	US/T-S	E
M: 31; 36	2001	US/T-S	E
C: <i>Aplysia dactylomela</i> Rang, 1828			
F: 6; 7; 10; 13; 14; 19; 21; 22; 23; 27; 28; 30	2013	US	E
M: 35	2013	US	C
C: <i>Percnon gibbesi</i> (H. Milne Edwards, 1853)			
F: 3; 4; 6; 14; 17; 19; 28; 30	2010	US/T-S	E
M: 32; 33; 34	2003	US/T-S	E
A: <i>Fistularia commersonii</i> Rüppell, 1838			
F: 18; 20	2014	US	E
M: 31	2005	US	C
C: <i>Kyphosus vaigiensis</i> (Quoy & Gaimard, 1825)			
F: 4	2013	US	C
A: <i>Stephanolepis diaspros</i> Fraser-Brunner, 1940			
M: 31	2014	US	C

Status: A alien, C cryptogenic. Known sites of occurrence per island: F Favignana, M Marettimo, L Levanzo. Plausible vectors: US unaided spread, T-S transport-stowaway. Establishment status (updated December 2015): C casual, E established

Egadi Islands MPA dates back to 2001 (Catra et al. 2006). Specimens were found in several sites along the coasts of the three main islands. At Favignana, it was recorded from 0 to 30 m depth, at Levanzo from 0 to 40 m depth, and at Marettimo from 0 to 25 m depth. From 2006 onwards, the alga was recorded again at Favignana, mainly on rocks between 0.5 and 6 m depth (R. D'Agostaro, unpublished data; P. Balistreri, unpublished data). Both unaided spread or

transport-stowaway may be plausible pathways of introduction for local specimens.

*Asparagopsis taxiformis* (Delile) Trevisan de Saint-Léon, 1845 complex (Fig. 2b)

**Status:** ALIEN SPECIES

**Remarks:** *Asparagopsis taxiformis* (Delile) Trevisan de Saint-Léon, 1845 was originally described by Delile (1813)

with Alexandria (Egypt, Mediterranean Sea) as type locality. Being mostly diffused in the Indo-Pacific, several authors considered it in the past as a Tethyan relict (Cormaci et al. 2004) or a pre-Lessepsian immigrant (Por 1978). However, recent molecular data showed that the *A. taxiformis* complex is composed of 5 different clades (type material, if existing, not yet barcoded), although the recent publication by Dijoux et al. (2014) did not resolve the taxonomic status of the known lineages. However, we here cautiously report it as a complex of species, also in agreement with previous studies by Andreakis et al. (2004, 2007, 2009). In addition to the taxonomic uncertainties reported above, the finding of central Mediterranean specimens clustering with Indo-Pacific specimens and of eastern Mediterranean specimens clustering with Atlantic specimens, suggests that one lineage (recently spreading in the central Mediterranean Sea) has to be considered alien, whilst another lineage (the eastern Mediterranean one) may be native to the area (Andreakis et al. 2004, 2007, 2009; Dijoux et al. 2014).

**Presence in the Egadi Islands MPA:** the first record of specimens belonging to this complex of species from the Egadi Islands MPA dates back to 2000 at Favignana (Barone et al. 2003a). From then on, its presence was regularly recorded at Favignana, both on the northern and the southern side, from sea level to 30 m depth (but mainly down to 20 m) on rock and sand, or as an epiphyte on *Posidonia oceanica* (Linnaeus) Delile, 1813 (R. D'Agostaro, unpublished data;

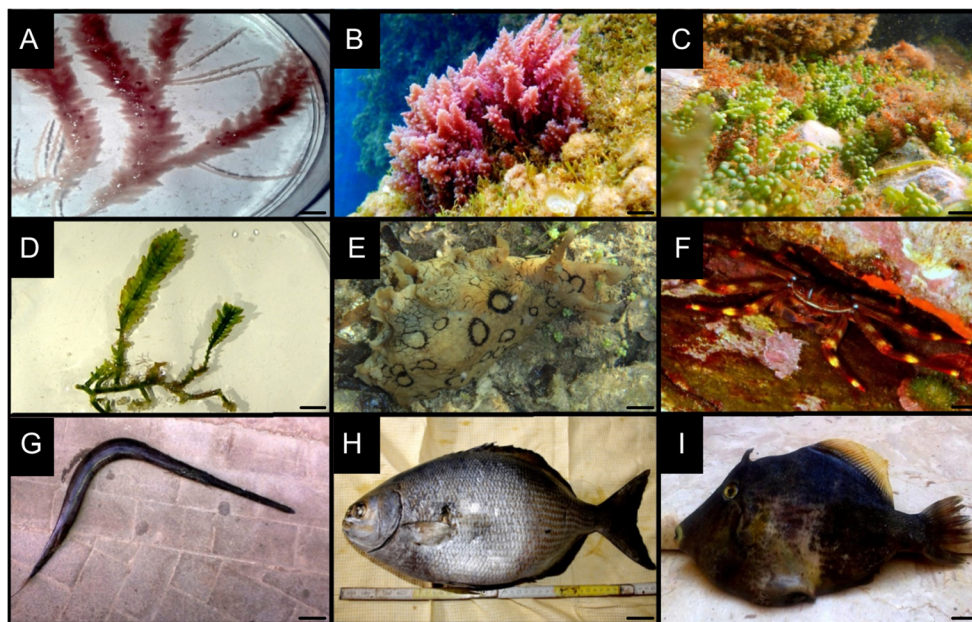
P. Balistreri, unpublished data). In 2015, specimens belonging to this complex were also reported from Levanzo (P. Balistreri and A.M. Mannino, unpublished data). Unfortunately, no barcoding studies have been made on Aegadian material, although the molecular analysis of specimens from the nearby areas (Trapani and Pantelleria, Italy, and Mahdia, Tunisia) would suggest that specimens spreading in the Egadi Islands MPA belong to the Indo-Pacific clade. We therefore here consider this species as alien, pending further studies. Currently, the pathway of introduction (unaided spread or transport-stowaway) of local specimens cannot be attributed with certainty. Certainly, the Trapani coast, where it was first reported in 2000 (first Italian record; Barone et al. 2003b), might be considered a possible centre of secondary dispersal.

*Bonnemaisonia hamifera* Hariot, 1891

**Status:** ALIEN SPECIES

**Remarks:** believed to be native to Japan (Dixon and Irvine 1977). It reached the Mediterranean Sea by 1909, being first recorded at La Galite (Tunisia, Petersen 1918). Only “*Trailiella*-phase” (tetrasporophytic thallus) is known from the Mediterranean Sea. Transport-stowaway is considered the plausible pathway of introduction in the Mediterranean Sea.

**Presence in the Egadi Islands MPA:** first reported from the Egadi Islands MPA in 2001 at Levanzo (40 m depth) and Favignana (1 m depth) (Catra et al. 2006). There are no further records of this species in the area. Both unaided spread or



**Fig. 2** Marine alien and cryptogenic species from the Egadi Islands MPA (Italy) recorded by the authors: **a** *Asparagopsis armata* Harvey, 1855 complex, scale bar 1.5 cm; **b** *Asparagopsis taxiformis* (Delile) Trevisan de Saint-Léon, 1845 complex, scale bar 1.5 cm; **c** *Caulerpa cylindracea* Sonder, 1845, scale bar 3 cm; **d** *Caulerpa taxifolia* (M. Vahl) C. Agardh, 1817, scale bar 1 cm; **e** *Aplysia dactylomela* Rang,

1828, scale bar 3 cm (Photo Stefano Melchioni); **f** *Percnon gibbesi* (H. Milne Edwards, 1853), scale bar 1 cm; **g** *Fistularia commersonii* Rüppell, 1838, scale bar 7 cm (Photo Vito Vaccaro); **h** *Kyphosus vaigiensis* (Quoy & Gaimard, 1825), scale bar 4 cm; **i** *Stephanolepis diaspros* Fraser-Brunner, 1940, scale bar 1.5 cm (Photo Vito Vaccaro)

transport-stowaway may be considered plausible pathways of introduction for local specimens.

*Botryocladia madagascariensis* G. Feldmann, 1945

**Status:** ALIEN SPECIES

**Remarks:** Madagascar is the type locality of this species. It was first reported from the Mediterranean Sea at Lampedusa Island and Castelluccio (Italy) in 1991 (Cormaci et al. 1992). Both unaided spread or transport-stowaway, through the Suez Canal, may be considered plausible pathways of introduction in the Mediterranean Sea.

**Presence in the Egadi Islands MPA:** first reported from the Egadi Islands MPA in 2001 at Favignana (0, 1 and 7 m depth) (Catra et al. 2006). There are no further records of this species in the area. Both unaided spread or transport-stowaway may be considered plausible pathways of introduction for local specimens.

*Caulerpa cylindracea* Sonder, 1845

(Fig. 2c)

**Status:** ALIEN SPECIES

**Remarks:** Until Belton et al. (2014), this species was often reported in the literature as *Caulerpa racemosa* var. *cylindracea* (Sonder) Verlaque, Huisman and Boudouresque. Native to Australia and New Caledonia (Belton et al. 2014), *Caulerpa cylindracea* Sonder, 1845 was first observed in the Mediterranean Sea in 1990 off the coast of Libya (Nizamuddin 1991).

**Presence in the Egadi Islands MPA:** first reported from the Egadi Islands MPA in 2003 at Favignana (Piazzini et al. 2005) and then in 2004 at Levanzo (ISPE 2007). The species was found on rock and sand in different habitats (e.g. *P. oceanica* meadows, vermetid reefs), both at sea level and between 15 and 30 m depth. Currently, *C. cylindracea* is widely distributed in the Egadi Islands. Unaided spread or transport-stowaway may both be plausible pathways of introduction for local specimens. Since it is a highly successful and fast-spreading species showing invasive behavior, in 2014 a public awareness project “*Caulerpa cylindracea* - Isole Egadi” was launched with the aim of creating a database on the dynamics of spreading and the invasiveness of *C. cylindracea* within the Egadi Islands MPA.

*Caulerpa taxifolia* (M. Vahl) C. Agardh, 1817 (invasive aquarium strain)

(Fig. 2d)

**Status:** ALIEN SPECIES

**Remarks:** originally described from the Virgin Islands (western Atlantic Ocean), *Caulerpa taxifolia* (M. Vahl) C. Agardh, 1817 was first recorded from the Mediterranean in 1984, where it was accidentally introduced by the Oceanographic Museum of Monaco (Meinesz and Hesse 1991; Jousson et al. 1998). Since then, the *C. taxifolia* invasive aquarium strain, genetically different from the ancestral Australian strain (Meusnier et al. 2004; Jongma et al. 2013),

rapidly became widespread in the northwestern Mediterranean Sea (Meinesz et al. 2001).

**Presence in the Egadi Islands MPA:** first reported from the Egadi Islands MPA in 2004 at Favignana (Gianguzza et al. 2006). It was found from sea level to 22 m depth on sand, mostly in *P. oceanica* and *Cymodocea nodosa* (Ucria) Ascherson, 1870 meadows. Both unaided spread or transport-stowaway may be considered plausible pathways of introduction for local specimens.

*Ceramium strobiliforme* G.W. Lawson & D.M. John, 1982

**Status:** ALIEN SPECIES

**Remarks:** Ghana is the type locality of this species. It was first reported from the Mediterranean Sea at Salina Island (Italy) in 1991 (Cormaci et al. 1992). Transport-stowaway is considered the plausible pathway of introduction in the Mediterranean Sea.

**Presence in the Egadi Islands MPA:** first reported from the Egadi Islands MPA in 2001 at Levanzo (0, 10 and 40 m depth) (Catra et al. 2006). There are no further records of this species in the area. Both unaided spread or transport-stowaway may be considered plausible pathways of introduction for local specimens.

*Laurencia caduciramulosa* Masuda & Kawaguchi, 1997

**Status:** ALIEN SPECIES

**Remarks:** Vietnam is the type locality of this species. It was first reported from the Mediterranean Sea at Lachea Island (Italy) in 1991 (Furnari et al. 2001). Transport-stowaway may be considered the plausible pathway of introduction in the Mediterranean Sea.

**Presence in the Egadi Islands MPA:** first reported from the Egadi Islands MPA in 2001 at Favignana and Marettimo (0 m depth) (Catra et al. 2006). There are no further records of this species in the area. Both unaided spread or transport-stowaway may be considered plausible pathways of introduction for local specimens.

*Lophocladia lallemandii* (Montagne) F. Schmitz, 1893

**Status:** ALIEN SPECIES

**Remarks:** The Red Sea is the type locality of this species. It was first reported from the Mediterranean Sea in Greece and Lybia in 1908 (Petersen 1918). Unaided spread through the Suez Canal is considered the plausible pathway of introduction in the Mediterranean Sea. This species, widespread throughout the tropics and subtropics (Boudouresque and Verlaque 2002), exhibits invasive behavior.

**Presence in the Egadi Islands MPA:** first reported from the Egadi Islands MPA in 2001 at Favignana (7 m depth), Levanzo (1, 10 and 20 m depth) and Marettimo (25 m depth) (Catra et al. 2006). There are no further records of this species in the area. Both unaided spread or transport-stowaway may be considered plausible pathways of introduction for local specimens.

*Neosiphonia harveyi* (J.W. Bailey) M.S. Kim, H.G. Choi, Guiry & G.W. Saunders, 2001

**Status:** ALIEN SPECIES

**Remarks:** Connecticut (USA) is the type locality of this species. It was first reported from the Mediterranean Sea in the Thau Lagoon (France) in 1958 (Lauret 1967 as *Polysiphonia mottei* Lauret). Escape from aquaculture facilities (according to CBD 2014) is considered the plausible pathway of introduction in the Mediterranean Sea.

**Presence in the Egadi Islands MPA:** first reported from the Egadi Islands MPA in 2001 at Favignana (20 m depth) and Levanzo (10 m depth) (Catra et al. 2006). There are no further records of this species in the area. Both unaided spread or transport-stowaway may be considered plausible pathways of introduction for local specimens.

*Womersleyella setacea* (Hollenberg) R.E. Norris, 1992

**Status:** ALIEN SPECIES

**Remarks:** It is native to tropical areas with the Hawaiian Islands considered the type locality. It was first reported from the Mediterranean Sea in 1986 in Italy as *Polysiphonia* sp. (Benedetti-Cecchi and Cinelli 1989) and in France in 1987 as *Polysiphonia setacea* Hollenberg (Verlaque 1989). Transport-stowaway is suggested to be the plausible pathway of introduction in the Mediterranean Sea. This species is considered one of the most harmful invasive species (Boudouresque and Verlaque 2002).

**Presence in the Egadi Islands MPA:** first reported from the Egadi Islands MPA in 2001 at Favignana (1–7, 10, 20 and 30 m depth), Levanzo (0, 5, 10, 20, 30 and 40 m depth) and Marettimo (10 and 25 m depth) (Catra et al. 2006). There are no further records of this species in the area. Both unaided spread or transport-stowaway may be considered plausible pathways of introduction for local specimens.

*Aplysia dactylomela* Rang, 1828

(Fig. 2e)

**Status:** CRYPTOGENIC SPECIES

**Remarks:** originally considered a circumtropical species, recent molecular studies revealed that Mediterranean specimens belong to *Aplysia dactylomela* Rang, 1828 (originating from the Atlantic) rather than to its cryptic Indo-Pacific congeneric species *Aplysia argus* Rüppell & Leuckart, 1830 (see Valdés et al. 2013). Although the genetic composition of Mediterranean populations of *A. dactylomela* is consistent with a natural dispersal through the Strait of Gibraltar, the hypothesis of a human-mediated introduction in the Mediterranean from Atlantic populations cannot be discarded (Valdés et al. 2013). First recorded in the Mediterranean Sea from Lampedusa (Sicily Channel, Italy) (Trainito 2003), its Mediterranean introduction vector is not yet established with certainty (see discussions above), and therefore we cautiously considered this species as cryptogenic.

**Presence in the Egadi Islands MPA:** first reported from the Egadi Islands MPA in 2013 at Favignana, likely dispersed naturally with veliger larvae carried by the current or by marine traffic (Mannino et al. 2014). Other records come from

Favignana (Cala Moni), between 0 and 1.5 m on rock and sand, and from Marettimo (Scalo Vecchio), at 5 m depth on rocks. The presence of a few specimens may either be the result of a recent event, and new populations will soon be sighted in the whole Egadi Islands and on the western and southern coasts of Sicily (Mannino et al. 2014), or the result of the low phase of the population cycle (Carefoot 1987; Pennings 1991). The presence of *A. dactylomela* in the Egadi Islands MPA might be a consequence of unaided spread by dispersal of larvae, as already hypothesised by Valdés et al. (2013) to explain its introduction in the Mediterranean Sea.

*Percnon gibbesi* (H. Milne Edwards, 1853)

(Fig. 2f)

**Status:** CRYPTOGENIC SPECIES

**Remarks:** a native Atlantic species, first recorded in the Mediterranean Sea in 1999 at Linosa (Pelagian Islands, Sicily Strait) (Relini et al. 2000). There is a general agreement to include *Percnon gibbesi* (H. Milne Edwards, 1853) among Mediterranean aliens. However, due to the large planktonic duration of its larvae that leads to long-range dispersal (Paula and Hartnoll 1989; Katsanevakis et al. 2011), Abelló et al. (2003) suggest that this species entered the Mediterranean transported by the Atlantic current and its spread was through natural dispersal. Given wide uncertainties regarding possible vectors, and as there are no molecular studies carried out to date, we hereby cautiously considered this species as cryptogenic.

**Presence in the Egadi Islands MPA:** first found in the Egadi Islands MPA in August 2003, when several specimens were observed on the northern side of Marettimo (Scalo Maestro, Libano and Punta Due Frati), on a rocky bottom at 1.5 m depth (P. Balistreri, unpublished data). One of these, a male specimen (carapace: 17.5 mm width and 17.0 mm length) has been deposited in the Casa Museo “Matteo Sercia” of Favignana with the accession number CCGS0002. In July 2010, the species was also recorded from Favignana, at Pirreca (on the south-western side) at 1 m depth, at Scalo San Leonardo (harbour) at 1 m depth and in many other areas of the island (P. Balistreri, unpublished data) between 0 and 2 m depth. For *P. gibbesi*, the pathway of introduction (unaided spread or transport-stowaway) in the Egadi Islands MPA remains questionable.

*Fistularia commersonii* Rüppell, 1838

(Fig. 2g)

**Status:** ALIEN SPECIES

**Remarks:** native to and widely distributed in the Indo-Pacific, *Fistularia commersonii* Rüppell, 1838 is a highly successful Lessepsian migrant, first recorded in the Mediterranean Sea in 2000, along the coast of Israel at 35 m depth (Golani 2000), from where in few years it spread all over the Mediterranean Sea (Azzurro et al. 2013).

**Presence in the Egadi Islands MPA:** first reported from the Egadi Islands MPA at Marettimo in 2005 (Castriota et al.



2014). In November 2014, two specimens were caught, using a trammel net, at Favignana (Scoglio Corrente and Preveto Islet), on a rocky bottom at about 45 m depth (P. Balistreri, unpublished data). These specimens were fixed in alcohol and deposited in the Casa Museo “Matteo Sercia” (with the accession numbers CPOGS0001 and CPOGS0002, respectively). In November 2014, another specimen (about 90 cm long) was caught, using a trammel net, in the waters off Punta Mugnone (Marettimo), on a rocky bottom at about 20 m depth (P. Balistreri, unpublished data). For *F. commersonii*, unaided spread is considered the most probable pathway of introduction.

*Kyphosus vaigiensis* (Quoy & Gaimard, 1825)  
(Fig. 2h)

**Status:** CRYPTOGENIC SPECIES

**Remarks:** a circumtropical species widely distributed both in the Atlantic and in the Indo-Pacific, often misidentified in the past as *Kyphosus incisor* (Cuvier, 1831), and recorded since 1998 from the Mediterranean Sea (Almuñécar, Granada, Spain) (see Mannino et al. 2015 for discussion and review). According to Zenetos et al. (2012), the records of this taxon should be considered as stemming from natural range expansion rather than human-mediated introduction. Mannino et al. (2015) recently discussed the status of *Kyphosus vaigiensis* (Quoy & Gaimard, 1825) in the Mediterranean, leaving open questions regarding a possible entry through the Suez Canal (including a transport-stowaway pathway) or the Strait of Gibraltar. Given the wide distribution reported in the literature, and being only recently recorded from the Mediterranean Sea, we here cautiously considered this species as cryptogenic.

**Presence in the Egadi Islands MPA:** a specimen molecularly identified as *K. vaigiensis* was first caught in September 2013 off Favignana, in shallow waters (approximately 3 m depth) on a hard bottom (Mannino et al. 2015). For *K. vaigiensis*, an unaided spread from neighbouring areas is a plausible pathway of introduction.

*Stephanolepis diaspros* Fraser-Brunner, 1940  
(Fig. 2i)

**Status:** ALIEN SPECIES

**Remarks:** widely distributed in the Indo-Pacific, and first recorded in the Mediterranean Sea in the Levantine Basin in 1927 (Steinitz 1927). *Stephanolepis diaspros* Fraser-Brunner, 1940 is considered one of the earlier Lessepsian immigrants and is actually established in the whole eastern part of the basin (Golani et al. 2015) and well distributed in its central part (Lipej et al. 2014; Deidun et al. 2015; Golani et al. 2015).

**Presence in the Egadi Islands MPA:** in 2014, an adult male of this species (about 17 cm long) was caught using a trammel net in the waters off Punta Mugnone (Marettimo), on a rocky bottom at about 20 m depth (Balistreri and Parasporo in Tsiamis et al. 2015). For *S. diaspros*, an unaided spread

from neighbouring areas may be a plausible pathway of introduction (see Deidun et al. 2015).

## Conclusions

As already mentioned above, the overall approach of this article has been precautionary. Indeed, for species capable of active or passive propagule dispersal, it may be difficult to establish their status with certainty from faunal data only (e.g. if a species is an alien or simply a naturally spreading species). Recently, Marchini et al. (2015) stressed the need for standardised definitions and criteria in compiling inventories of marine alien species. Yet, the inclusion or not of a species among aliens is often purely a matter of semantics. Some of the species considered as cryptogenic may turn out to be recent natural entries in the Mediterranean Sea, but since they show invasive behavior, a careful monitoring of their spreading may be necessary independently from whether or not they are aliens.

Among the species listed here from the Egadi Islands MPA, macrophytes are the dominant group. The overall analysis of published and unpublished sightings (Table 2) clearly shows that Favignana is the island of the Egadi Islands MPA most affected by the introduction of alien and cryptogenic species, with species widely distributed all around the coastline. This is consistent with the central position of Favignana, both from a geographical and a transport-stowaway point of view; it is the island nearest to the Trapani coast and it is the one with more intense traffic of recreational, fishing or commercial boats, and with more tourists.

The identification of pathways of introduction of alien species at regional and local levels is a priority in order to manage the spread of species already introduced and to adopt preventive measures. The analysis of possible pathways of introduction in the Egadi Islands MPA showed that unaided spread is a plausible vector of arrival in the area for all the species analysed. However, a transport-stowaway (e.g. fishing, recreational boating, tourism)-mediated introduction cannot be totally rejected for several of the taxa listed, including all macrophytes, also considering the dynamics of spreading of these macrophytes after their entrance in the Mediterranean Sea.

Maritime traffic, visits by boats, ports and marinas may certainly lead to an increase of marine introductions, and can produce a constant spillover of new invaders into surrounding areas such as MPAs, contributing to their successful establishment (Otero et al. 2013). In agreement with the hypothesis suggested for other archipelagos (e.g. Evans et al. 2015; Schembri et al. 2015), we think that the regular and heavy transport-stowaway (recreational and/or commercial) potential between Sicily and the Egadi Islands MPA, and particularly Favignana, may have contributed to the arrival of sessile taxa often recorded in fouling communities. Whatever the true

pathway (unaided spread or transport-stowaway), Sicily and/or the surrounding islands may represent an important centre of secondary dispersal for the Egadi Islands MPA.

All the species listed were recorded after the Egadi Islands MPA was established, with the first record dating back to 2000. However, this does not allow us to draw any conclusions about the effectiveness or ineffectiveness of the MPA in stopping local introductions. Indeed, this may be easily explained by the recent increase in research programs on marine reserves. Since areas located at the crossroads between the eastern and western sectors of the Mediterranean, like Sicily and the circum-Sicilian islands, are more vulnerable to marine biological invasions, regular monitoring programs, including public awareness campaigns, are strongly needed not only within MPAs but also in their surroundings in order to manage continuous spillover effects (see also Otero et al. 2013).

Moreover, in spite of their fundamental role in conservation of marine biodiversity, MPAs have been widely demonstrated to be ineffective in stopping local introductions, and therefore an invasive alien species (IAS) strategy integrated into the management plan may be highly desirable.

The creation of a permanent observatory involving all Sicilian MPAs, able to early detect new introductions and to follow the spread of species already present might be an effective tool in the management of present and future introductions of alien species in the MPAs and in neighboring areas.

**Acknowledgments** The authors thank Ernesto Azzurro, Luca Castriota, Stefano Melchioni, Gabriele Sercia, Vito Vaccaro and Bruno Zava for providing photos, information and records. They also thank Dr. Elisabetta Oddo for improving the English text. The study of the alien species from Italy was partially funded by the East and South European Network for Invasive Alien Species—a tool to support the management of alien species in Bulgaria (ESENIA-S-TOOLS) (EEA funded: Contract No. Д-33-51/30.06.2015) (FC).

## References

- Abelló P, Visauta E, Bucci A, Demestre M (2003) Noves dades sobre l'expansió del cranc *Percnon gibbesi* (Brachyura: Grapsidae: Plagusinae) a la Mediterrània occidental. *Boll Soc Hist Nat Balears* 46:73–77
- Andreakis N, Procaccini G, Kooistra W (2004) *Asparagopsis taxiformis* and *Asparagopsis armata* (Bonnemaisoniales, Rhodophyta): genetic and morphological identification of Mediterranean populations. *Eur J Phycol* 39:273–283
- Andreakis N, Procaccini G, Maggs C, Kooistra WHCF (2007) Phylogeography of the invasive seaweed *Asparagopsis* (Bonnemaisoniales, Rhodophyta) reveals cryptic diversity. *Mol Ecol* 16:2285–2299
- Andreakis N, Kooistra WHCF, Procaccini G (2009) High genetic diversity and connectivity in the polyploid invasive seaweed *Asparagopsis taxiformis* (Bonnemaisoniales) in the Mediterranean, explored with microsatellite alleles and multilocus genotypes. *Mol Ecol* 18:212–226
- Azzurro E, Soto S, Garofalo G, Maynou F (2013) *Fistularia commersonii* in the Mediterranean Sea: invasion history and distribution modeling based on presence-only records. *Biol Invasions* 15(5):977–990
- Barone R, Di Martino V, Mannino AM (2003a) *Asparagopsis taxiformis* (Delile) Trevisan in Sicily: distribution and reproductive strategies. Third European Phycological Congress (EPC3, Belfast, Ireland)
- Barone R, Mannino AM, Marino M (2003b) *Asparagopsis taxiformis* (Bonnemaisoniales, Rhodophyta): first record of gametophytes on the Italian coast. *Bocconea* 16(2):1021–1025
- Bax N, Williamson A, Aguero M, Gonzales E, Geeves W (2003) Marine invasive alien species: a threat to global biodiversity. *Mar Policy* 27: 313–323
- Belton GS, Prud'homme van Reine WF, Huisman JM, Draisma SGA, Gurgel CFD (2014) Resolving phenotypic plasticity and species designation in the morphologically challenging *Caulerpa racemosa-peltata* complex (Chlorophyta, Caulerpaceae). *J Phycol* 50:32–54
- Benedetti-Cecchi L, Cinelli F (1989) Note on a *Polysiphonia* sp. (Rhodophyta, Ceramiales) collected at Rosignano Solvay (Western Mediterranean). *Giorn Bot Ital* 123:49–54
- Berthold G (1882) Die Bangiaceen des Golfes von Neapel und der angrenzenden Meeres-Abschnitte. *Fauna Flora Golfes Neapel*, Monographie 8. Englemann, Leipzig
- Bianchi CN (2007) Biodiversity issues for the forthcoming tropical Mediterranean Sea. *Hydrobiologia* 580:7–21
- Bouchet P (2015) *Pinctada imbricata radiata* (Leach, 1814). In: MolluscaBase (2015) World register of marine species. <http://marinespecies.org/aphia.php?p=taxdetails&id=564660>
- Boudouresque CF, Verlaque M (2002) Biological pollution in the Mediterranean Sea: invasive versus introduced macrophytes. *Mar Pollut Bull* 44:32–38
- Britton-Simmons KH, Abbott KC (2008) Short- and long-term effects of disturbance and propagule pressure on a biological invasion. *J Ecol* 96:68–77
- Burfeind DD, Pitt KA, Connolly RM, Byers JE (2013) Performance of invasive species within marine reserves. *Biol Invasions* 15:17–28
- Byers JE (2005) Marine reserves enhance abundance but not competitive impacts of a harvested nonindigenous species. *Ecology* 86:487–500
- Carefoot TH (1987) *Aplysia*: its biology & ecology. *Oceanogr Mar Biol Annu Rev* 25:167–284
- Carlton JT (1996) Biological invasions and cryptogenic species. *Ecology* 77(6):1653–1655
- Carlton JT (2009) Deep invasion ecology and the assembly of communities in historical time. In: Rilov G, Crooks J (eds) *Biological invasions in marine ecosystems*. Springer, Berlin, pp 13–56
- Castriota L, Falautano M, Battaglia P, Oddo A, Andaloro F (2014) New biological data on *Fistularia commersonii* in the central Mediterranean Sea. *Cybiurn* 38(1):15–21
- Catra M, Alongi G, Serio D, Cormaci M, Furnari G (2006) The benthic algal flora on rocky substrata of the Egadi Islands, a marine protected archipelago off the western coast of Sicily (Italy, Mediterranean Sea). *Nova Hedwigia* 82:489–538
- [CBD] Convention on Biological Diversity (2014) Pathways of Introduction of Invasive Species, Their Prioritization, and Management. CBD (5 May 2014; [www.cbd.int/doc/meetings/sbstta/sbstta-18/official/sbstta-18-09-add1-en.pdf](http://www.cbd.int/doc/meetings/sbstta/sbstta-18/official/sbstta-18-09-add1-en.pdf))
- Coll M, Piroddi C, Steenbeek J, Kaschner K, Ben Rais Lasram F, Aguzzi J, Ballesteros E, Bianchi CN, Corbera J, Dailianis T, Danovaro R, Estrada M, Froggia C, Galil BS, Gasol JM, Gertwagen R, Gil J, Guilhaumon F, Kesner-Reyes K, Kitsos MS, Koukouras A, Lampadariou N, Laxamana E, López-Fé de la Cuadra CM, Lotze HK, Martin D, Mouillot D, Oro D, Raicevich S, Rius-Barile J, Saiz-Salinas JJ, San Vicente C, Somot S, Templado J, Turon X, Vafidis D, Villanueva R, Voultsiadou E (2010) The biodiversity of the Mediterranean Sea: estimates, patterns and threats. *PLoS ONE* 5(8):e11842. doi:10.1371/journal.pone.0011842

- Cormaci M, Furnari G, Alongi G, Dinaro R, Pizzuto F (1992) On the occurrence in Sicily of three Florideophyceae new to the Mediterranean Sea. *Bot Mar* 35:447–450
- Cormaci M, Furnari G, Giaccone G, Serio D (2004) Alien macrophytes in the Mediterranean Sea: a review. *Recent Res Devel Environ Biol* 1: 153–202
- Crocetta F, Renda W (2008) Further record of *Chlamys lischkei* (Bivalvia: Pectinoidea) in the Mediterranean Sea. *Mar Biodiv Rec* 1:e57. doi:10.1017/S1755267207006045
- Deidun A, Castriota L, Falautano M, Maraventano G, Prazzi E, Andaloro F (2015) Documenting the occurrence of the Lessepsian fish *Stephanolepis diaspros* within the Strait of Sicily, central Mediterranean. *J Black Sea/Medit Environ* 21(1):1–11
- Delile AR (1813) *Florae Aegyptiacae illustratio*. In: Anon (ed) *Description de l’Egypte ou recueil des observations et des recherches qui ont été faites en Egypte pendant l’expédition de l’armée française (1798–1801), Histoire naturelle, Vol. 2*, Paris: France (Commission d’Egypte), pp 49–82
- Dijoux L, Viard F, Payri C (2014) The more we search, the more we find: discovery of a new lineage and a new species complex in the genus *Asparagopsis*. *PLoS ONE* 9(7):e103826. doi:10.1371/journal.pone.0103826
- Dixon PS, Irvine LM (1977) *Seaweeds of the British Isles. Volume 1 Rhodophyta. Part 1 Introduction, Nemaliales, Gigartinales*. The Natural History Museum, London
- EC (European Commission) (2008) *Developing an EU framework for invasive alien species discussion paper (Final)*. [http://ec.europa.eu/environment/nature/invasivealien/docs/ias\\_discussion\\_paper.pdf](http://ec.europa.eu/environment/nature/invasivealien/docs/ias_discussion_paper.pdf).
- Evans J, Barbara J, Schembri PJ (2015) Updated review of marine alien species and other ‘newcomers’ recorded from the Maltese Islands (Central Mediterranean). *Mediterr Mar Sci* 16(1):225–244
- Feldman J, Feldman G (1942) *Récherches sur les Bonnemaisoniacées et leur alternance de génération*. *Ann Sci Nat Bot Ser* 11(3):75–175
- Furnari G, Cormaci M, Serio D (2001) The *Laurencia* complex (Rhodophyta, Rhodomelaceae) in the Mediterranean Sea: on over-view. *Cryptogamie, Algol* 22:331–373
- Galil BS (2007) Loss or gain? Invasive aliens and biodiversity in the Mediterranean Sea. *Mar Pollut Bull* 55:314–322
- Galil BS, Goren M (2014) *Metamorphoses: bioinvasions in the Mediterranean Sea*. In: Goffredo S, Dubinsky Z (eds) *The Mediterranean Sea*. Springer, Dordrecht, pp 463–478
- Galil B, Boero F, Frascchetti S, Piraino S, Campbell M, Hewitt C, Carlton J, Cook E, Jelmert A, Macpherson E, Marchini A, Occhipinti-Ambrogi A, Mckenzie C, Minchin D, Ojaveer H, Olenin S, Ruiz G (2015) The enlargement of the Suez Canal and introduction of non-indigenous species to the Mediterranean Sea. *Bull Limnol Oceanog* 24(2):25–64
- Galil BS, Marchini A, Occhipinti-Ambrogi A (2016) East is east and West is west? Management of marine bioinvasions in the Mediterranean Sea. *Estuar Coast Shelf S*. doi:10.1016/j.ecss.2015.12.021
- Gianguzza P, Zava B, Bonaviri C, Monteverde G, Palmeri A, Riggio S (2006) First record of *Caulerpa taxifolia* (Caulerpales, Ulvophyceae) in the western Sicilian waters (Italy). *Biol Mar Medit* 13(1):591–592
- Golani D (2000) First record of the bluespotted cornetfish from the Mediterranean Sea. *J Fish Biol* 56:1545–1547
- Golani D, Orsi-Relini L, Massutí E, Quignard JP, Dulčić J, Azzurro E (2015) *CIESM atlas of exotic fishes in the Mediterranean*. <http://www.ciesm.org/atlas/appendix1.html>
- Gubbioli F, Nofroni I (1985) *Note malacologiche dal mare di Alboran (Mediterraneo occidentale)*. *Contributo 1. La Conchiglia* 17(200–201):20–21
- ISPE (2007) *Monitoraggio dei popolamenti ittici presenti nei caulerpeti alloctoni siciliani*. ISPE ed., Palermo
- Jongma DN, Campo D, Dattolo E, D’Esposito D, Duchi A, Grewe P, Huisman J, Verlaque M, Yokes MB, Procaccini G (2013) Identity and origin of a slender *Caulerpa taxifolia* strain introduced into the Mediterranean Sea. *Bot Mar* 56:27–39
- Jousson O, Pawlowski J, Zaninetti L, Meinesz A, Boudouresque CF (1998) Molecular evidence for the aquarium origin of the green alga *Caulerpa taxifolia* introduced to the Mediterranean Sea. *Mar Ecol Progr Ser* 172:275–280
- Katsanevakis S, Poursanidis D, Yokes MB, Mačić V, Beqiraj S, Kashta L, Sghaier YR, Zakhama-Sraieb R, Benamer I, Bitar G, Bouzaza Z, Magni P, Nike Bianchi C, Tsiakkiros L, Zenetos A (2011) Twelve years after the first report of the crab *Percnon gibbesi* (H. Milne Edwards, 1853) in the Mediterranean: current distribution and invasion rates. *J Biol Res-Thessalon* 16:224–236
- Katsanevakis S, Bogucarskis K, Gatto F, Vandekerckhove J, Deriu I, Cardoso AC (2012) Building the European Alien Species Information Network (EASIN): a novel approach for the exploration of distributed alien species data. *BioInvasions Rec* 1(4):235–245
- Katsanevakis S, Zenetos A, Belchior C, Cardoso AC (2013) Invading European Seas: assessing pathway of introduction of marine aliens. *Ocean Coast Manag* 76:64–74
- Katsanevakis S, Coll M, Piroddi C, Steenbeek J, Ben Rais Lasram F, Zenetos A, Cardoso AC (2014) Invading the Mediterranean Sea: biodiversity patterns shaped by human activities. *Front Mar Sci* 1: 32. doi:10.3389/fmars.2014.00032
- Klinger T, Padilla DK, Britton-Simmons K (2006) Two invaders achieve higher densities in reserves. *Aquat Conserv-Mar Freshw Eco* 16:30–311
- Lauret M (1967) *Morphologie, Phenologie, repartition des Polysiphonia marins du littoral languedocien. I. Section Oligosiphonia*. *Nat Monspel ser Bot* 18:347–373
- Lejeune C, Chevaldonne P, Pergent-Martini C, Boudouresque CF, Perez T (2010) Climate change effects on a miniature ocean: the highly diverse, highly impacted Mediterranean Sea. *Trends Ecol Evol* 25: 250–260
- Lipej L, Mavrič B, Dulčić J (2014) Northernmost record of the reticulated leatherjacket *Stephanolepis diaspros* Fraser-Brunner, 1940 in the Mediterranean Sea. *Mediterr Mar Sci* 15(1):198–212
- Mannino AM, Balistreri P, Yokeş MB (2014) First record of *Aplysia dactylomela* (Opisthobranchia, Aplysiidae) from the Egadi Islands (western Sicily). *Mar Biodiv Rec* 7:e22. doi:10.1017/S1755267214000190
- Mannino AM, Balistreri P, Iacofano D, Galil BS, Lo Brutto S (2015) An additional record of *Kyphosus vaigiensis* (Quoy & Gaimard, 1825) (Osteichthyes, Kyphosidae) from Sicily clarifies the confused situation of the Mediterranean kyphosids. *Zootaxa* 3963(1):045–054
- Marchini A, Galil BS, Occhipinti-Ambrogi A (2015) Recommendations on standardizing lists of marine alien species: lessons from the Mediterranean Sea. *Mar Poll Bull* 101:267–273
- Meinesz A, Hesse B (1991) Introduction et invasion de l’algue tropicale *Caulerpa taxifolia* en Méditerranée Nord occidentale. *Oceanol Acta* 14(4):415–426
- Meinesz A, Belsher T, Thibaut T, Antolic B, Mustapha KB, Boudouresque CF, Chiaverini D, Cinelli F, Cottalorda JM, Djellouli A, El Abed A, Orestano C, Grau AM, Ivesa L, Jaklin A, Langar H, Massuti-Pascual E, Peirano A, Tunesi L, De Vaugelas J, Zavodnik N, Zuljevic A (2001) The introduced green alga *Caulerpa taxifolia* continues to spread in the Mediterranean. *Biol Invasions* 3: 201–210
- Meusnier I, Valero M, Olsen JL, Stam WT (2004) Analysis of rDNA ITS1 indels in *Caulerpa taxifolia* (Chlorophyta) supports a derived, incipient species status for the invasive strain. *Eur J Phycol* 39:83–92

- Minchinton TE, Bertness MD (2003) Disturbance-mediated competition and the spread of *Phragmites australis* in a coastal marsh. *Ecol Appl* 13:1400–1416
- Nizamuddin M (1991) The green marine algae of Libya. *Elga*, Bern
- Occhipinti-Ambrogi A, Marchini A, Cantone G, Castelli A, Chimenz C, Cormaci M, Frogliola C, Furnari G, Gambi MC, Giaccone G, Giangrande A, Gravili C, Mastrototaro F, Mazziotti C, Orsi-Relini L, Piraino S (2011a) Alien species along the Italian coasts: an overview. *Biol Invasions* 13:215–237
- Occhipinti-Ambrogi A, Marchini A, Cantone G, Castelli A, Chimenz C, Cormaci M, Frogliola C, Furnari G, Gambi MC, Giaccone G, Giangrande A, Gravili C, Mastrototaro F, Mazziotti C, Orsi-Relini L, Piraino S (2011b) Erratum to: alien species along the Italian coasts: an overview. *Biol Invasions* 13:531–532
- Otero M, Cebrian E, Francour P, Galil B, Savini D (2013) Monitoring marine invasive species in Mediterranean marine protected areas (MPAs): a strategy and practical guide for managers. IUCN, Malaga (Spain)
- Paula J, Hartnoll RG (1989) The larval and post-larval development of *Percnon gibbesi* (Crustacea, Brachyura, Grapsidae) and the identity of the larval genus *Pluteocaris*. *J Zool Lond* 218:17–37
- Pennings SC (1991) Spatial and temporal variation in recruitment of *Aplysia californica* Cooper: patterns, mechanisms and consequences. *J Exp Mar Biol Ecol* 146:253–274
- Petersen HE (1918) Algae (excluding calcareous algae). *Rep Danish Oceanog Biology (Exped. 1908–1910 Medit. adj. seas)* 2:1–20
- Piazzi L, Meinesz A, Verlaque M, Akçali B, Antolić B, Argyrou M, Balata M, Ballesteros E, Calvo S, Cinelli F, Cirik S, Cossu A, D'Archino F, Djellouli AS, Javel F, Lanfranco E, Mifsud C, Pala D, Panayotidis P, Peirano A, Pergent G, Petrocelli A, Ruitton S, Žuljević A, Ceccherelli G (2005) Invasion of *Caulerpa racemosa* var. *cylindracea* (Caulerpales, Chlorophyta) in the Mediterranean Sea: an assessment of the spread. *Cryptogamie, Algol* 26(2):189–202
- Por FD (1978) Lessepsian migration. The influx of Red Sea biota into Mediterranean by way of the Suez Canal. *Ecological Studies*, 23. Springer, Berlin
- Relini M, Orsi L, Puccio V, Azzurro E (2000) The exotic crab *Percnon gibbesi* (H. Milne-Edwards, 1853) (Decapoda, Grapsidae) in the Central Mediterranean. *Sci Mar* 64:337–340
- Repetto G (1989) Nuovo ritrovamento in Mediterraneo di *Chlamys lischkei* (Bunker, 1850). *Boll Malacol* 25:261–262
- Schembri PJ, Barbara J, Deidun A, Lanfranco E, Lanfranco S (2015) It was only a matter of time: occurrence of *Caulerpa taxifolia* (Vahl) C. Agardh var. *distichophylla* (Sonder) Verlaque, Huisman and Procaccini in the Maltese Islands (Chlorophyta, Ulvophyceae, Caulerpaceae). *BioInvasions Rec* 4(1):9–16
- Steinitz W (1927) Beiträge zur Kenntnis der Küstenfauna Palästinas. I. *Pubbl Staz Zool Napoli* 8(3–4):311–353
- Trainito E (2003) Mediterranean harlequins, a field guide to Mediterranean sea slugs. *Taphros*, Olbia (Italy)
- Tsiamis K, Aydoğan Ö, Bailly N, Balistreri P, Bariche M, Carden-Noad S, Corsinifoka M, Crocetta F, Davidov B, Dimitriadis C, Dragičević B, Drakulić M, Dulčić J, Escáñez A, Fernández-Álvarez FA, Gerakaris V, Gerovasileiou V, Hoffman R, Izquierdo-Gómez D, Izquierdo-Muñoz A, Kondylatos G, Latsoudis P, Lipej L, Madiraca F, Mavrič B, Parasporo M, Sourbès L, Taşkin E, Türker A, Yapici S (2015) New Mediterranean biodiversity records (July 2015). *Mediterr Mar Sci* 16(2):472–488
- Valdés A, Alexander J, Crocetta F, Yokes B, Giacobbe S, Poursanidis D, Zenetos A, Cervera JL, Caballer M, Galil B, Schembri P (2013) The origin and dispersal pathway of the spotted sea hare *Aplysia dactylomela* (Mollusca: Opisthobranchia) in the Mediterranean Sea. *Aquat Invasions* 8:427–436
- Verlaque M (1989) Contribution à la flore des algues marines de Méditerranée: espèces rares ou nouvelles pour les côtes françaises. *Bot Mar* 32:101–113
- Wallentinus I, Nyberg CD (2007) Introduced marine organisms as habitats modifiers. *Mar Pollut Bull* 55:323–332
- West EJ, Barnes P, Wright J, Davis A (2007) Anchors aweigh: fragment generation of invasive *Caulerpa taxifolia* by boat anchors and its resistance to desiccation. *Aquat Bot* 87:196–202
- Zenetos A, Gofas S, Russo G, Templado J (2004) Molluscs. In: Briand F (ed) *CIESM atlas of exotic species in the Mediterranean*, vol 3. CIESM Publishers, Monaco, pp 1–380
- Zenetos A, Gofas S, Verlaque M, Çinar ME, García Raso JE, Bianchi CN, Morri C, Azzurro E, Bilecenoglu M, Frogliola C, Siokou I, Violanti D, Sfriso A, San Martín G, Giangrande A, Katağan T, Ballesteros E, Ramos Espla A, Mastrototaro F, Ocaña O, Zingone A, Gambi MC, Streftaris N (2010) Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part I. Spatial distribution. *Mediterr Mar Sci* 11(2):381–493
- Zenetos A, Gofas S, Morri C, Rosso A, Violanti D, García Raso JE, Çinar ME, Almogi-Labin A, Ates AS, Azzurro E, Ballesteros E, Bianchi CN, Bilecenoglu M, Gambi MC, Giangrande A, Gravili C, Hyams-Kaphzan O, Karachle PK, Katsanevakis S, Lipej L, Mastrototaro F, Mineur F, Pancucci-Papadopoulou MA, Ramos Esplá A, Salas C, San Martín G, Sfriso A, Streftaris N, Verlaque M (2012) Alien species in the Mediterranean Sea by 2012. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part 2. Patterns in introduction trends and pathways. *Mediterr Mar Sci* 13(2):328–352