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MONOGRAPH

Preliminary data on the occurrence of alien macroalgae in the vermetid reef along the coasts of Favignana Island (Southern Tyrrhenian Sea)

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ABSTRACT Intertidal vermetid reefs are highly diverse systems that provide numerous habitats for animal and vegetal species, leading to an increase of intertidal biodiversity. These habitats, particularly vulnerable to environmental changes and human activities, are now experiencing high mortality in several areas of the Mediterranean Sea. Since alien macroalgae are nowadays considered one of the most serious threats to biodiversity and natural ecosystem functioning, we provide a first baseline assessment of the occurrence of alien species in the vermetid reef along the coasts of the Island of Favignana (Egadi Islands Marine Protected Area). Surveyes carried out in 2015 revealed the only presence of *Caulerpa cylindracea* Sonder (Bryopsidales Caulerpaceae). The alga, exclusively recorded within the cuvettes, showed low values of abundance (class 1: cover <10%) except for San Giuseppe and Punta Longa localities where the values of abundance fell within the class 3 (cover <40% and >20%). No significant correlations were highlighted between the abundance values of *C. cylindracea* and those of the dominant macroalgae inhabiting the cuvettes.

KEY WORDS Alien macroalgae; Favignana Island; southern Tyrrhenian Sea; vermetid reef.

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INTRODUCTION

The Mediterranean Sea is one of the most severely affected areas by biological invasions, a "sea under siege" (Galil, 2000; Boudouresque et al., 2005; Rilov & Galil, 2009). The number of alien marine species reported so far ranges from more than 600 to nearly 1.000 (Zenetos et al., 2012; Galil & Goren, 2014). As far as marine macrophytes are concerned, a total of one hundred and thirty three species have been listed as possible aliens; of these, 23 belong to the Chlorophyta, 79 to the Rhodophyta, 30 to the Ochrophyta, and one is a seagrass species (Tracheophyta) (Verlaque et al., 2015). At present, 52 non-indigenous macroalgae are reported from the Italian coasts, 6 Chlorophyta, 9 Ochrophyta, 36 Rhodophyta and 1 aquatic angiosperm (Sfriso & Marchini, 2014). Among them the invasive taxa belonging to the genus *Caulerpa* (Bryopsidales Caulerpaceae), *Caulerpa racemosa* var. *cylindracea* (Sonder) Verlaque, Huisman et Boudouresque, thereafter reinstated to its species rank as *C. cylindracea* Sonder (Belton et al., 2014), *C. taxifolia* (Vahl) C. Agardh and *C. taxifolia* (Vahl) C.

Agardh var. *distichophylla* (Sonder) Verlaque, Huisman et Procaccini, recently recorded in Sicily (in 2007 as *C. distichophylla* in Meisnez et al., 2010; Jongma et al., 2013; Musco et al., 2014), have raised serious ecological and economic concern.

Sicily and smaller surrounding Islands, located at the crossroads between the eastern and western sectors of the Mediterranean Sea and characterized by intense maritime traffic (Occhipinti-Ambrogi et al., 2011; Coll et al., 2012; Katsanevakis et al., 2014), are particularly vulnerable and suitable to biological marine invasions (Bianchi, 2007; Occhipinti-Ambrogi et al., 2011; Katsanevakis et al., 2012; Papini et al., 2013; see also Figs. 2-5 in Katsanevakis et al., 2014) and then can be considered as important sources for secondary dispersal. Vermetid reefs are bioconstructions built up by the gastropod mollusc *Dendropoma cristatum* (Biondi, 1859) (Vermetidae) in association with some coralline algae such as *Neogoniolithon brassica-florida* (Harvey) Setchell et Mason. These bioconstructions play a fundamental structural role, as they protect coasts from erosion, regulate sediment transport and accumulation, serve as carbon sinks, make the habitat more complex and heterogeneous and provide numerous habitats for animal and vegetal species thus increasing intertidal biodiversity (Pandolfo et al., 1992, 1996; Badalamenti et al., 1998).

These biogenic constructions, enclosed in the SPA/BIO Protocol (Barcelona Convention) are now threatened by environmental changes and human activities (e.g. pollution, climate change, ocean acidification) thus experiencing high mortality in several areas of the Mediterranean Sea (Di Franco et al., 2011; Galil, 2013; Milazzo et al., 2014). Marine Protected Areas (MPAs), even though have a strong potential for habitat and biodiversity conservation, seem to be not effective in protecting from the different threats and then from biological invasions, sometimes enhancing them (e.g. Byers, 2005; Klinger et al., 2006; Burfeind et al., 2013). Since the increase of knowledge is essential for the conservation and protection of this highly valuable and vulnerable habitat, with this study we provide a first baseline assessment of the distribution and abundance of alien macroalgae in the vermetid reefs present along the coasts of Favignana Island (Egadi Islands MPA).

MATERIAL AND METHODS

Study area

The study was carried out at Favignana Island (Egadi Islands MPA), located approximately five kilometers from the western coast of Sicily. The Island, part of the Aegadian Archipelago, represents an example of a lower Pleistocene bioclastic calcarenite, characterized by a typic association known as foramol (Kil, 2010). More or less continuous vermetid reefs are present along the coasts of Favignana, consistent with the true reefs described along the north-western Sicilian coasts (Antonioli et al., 1999; Chemello, 2009). Their distribution confirms the need of carbonatic substrates and of an abrasion platform for the formation of true reefs (Dieli et al., 2001). Recently, a preliminary description of the reefs present along the coasts of Favignana Island was provided (Balistreri et al., 2015; Table 1).

Sampling and Data analysis

Surveys were carried out in summer 2015 in ten areas, characterized by the presence of a vermetid reef (Fig. 1). Five areas were selected along the northern side: Faraglione, Pozzo, Arre Turinu, San Giuseppe, San Nicola, and five along the southern side:

Pattern 1	**Outer Margin**: wide, flattened and irregular. In the inner side, crevices were also present. **Inner Margin**: *Dendropoma cristatum* is absent. **Cuvettes**: not many, not deep and with a variable width.
Pattern 2	**Outer Margin**: thin and not continuously arranged. **Inner Margin**: *Dendropoma cristatum* is absent. **Cuvettes**: not many and not deep.
Pattern 3	**Outer Margin**: it has a variable height and sometimes it is absent. Some crevices can also be present together with regrowth areas. **Inner Margin**: *Dendropoma cristatum* is absent. **Cuvettes**: many and sometimes very deep.

Table 1. Local patterns of vermetid reef observed at Favignana Island (Balistreri et al., 2015).

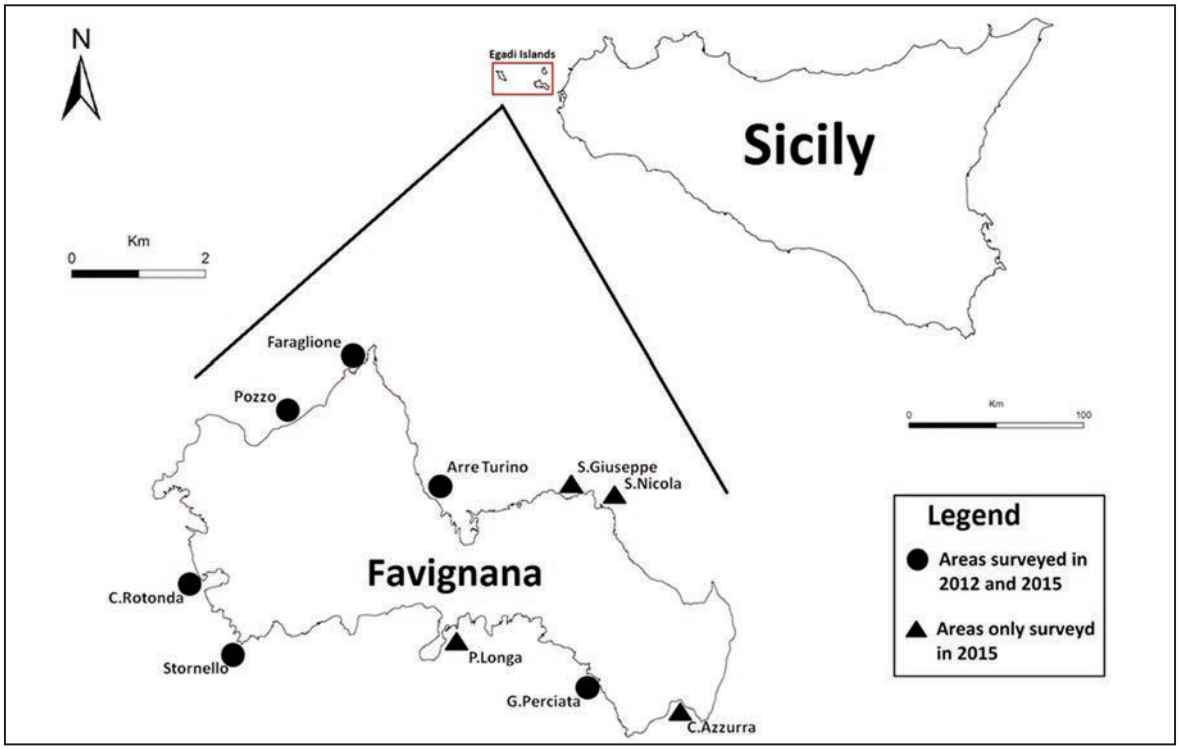
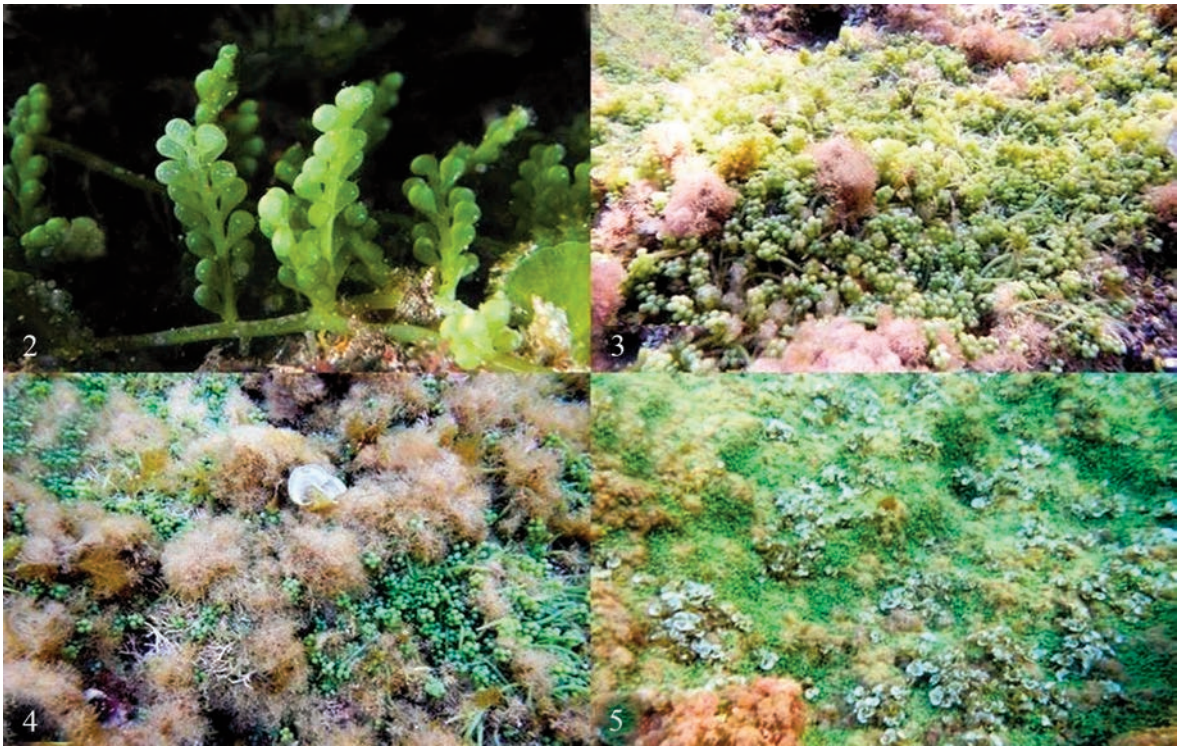


Figure 1. Location of the study areas at Favignana Island.



Figures 2–5. *Caulerpa cylindracea*. Fig. 2: Habit (photo by Fabio Russo). Figs. 3, 4: Patches within cuvettes, the stolons of *Caulerpa cylindracea* are strictly intermingled with the thalli of other macroalgae (San Giuseppe). Fig. 5: A patch beneath the reef (San Giuseppe).

Grotta Perciata, Cala Rotonda, Stornello, Punta Longa, Cala Azzurra. These areas were surveyed in order to check the presence of alien macroalgae. Six of the studied areas (Faraglione, Pozzo, Arre Turinu, Grotta Perciata, Cala Rotonda, Stornello) were already checked for the presence of alien species in summer 2012 (Balistreri, 2011/2012). The macroalgal community inhabiting the reef was also analysed in terms of abundance values of the dominant taxa. Abundance values of the alien taxa together with those of the dominant macroalgae were estimated, as substratum cover (%), by placing six replicated 400 cm^2 quadrats within the colonized surface, and five classes were considered: 1 (cover <10%), 2 (cover <20% and >10%), 3 (cover <40% and >20%), 4 (cover <60% and >40%) and 5 (cover >60%).

RESULTS

The surveys showed the only presence of *C. cylindracea* (Fig. 2), generally forming isolated patches within the cuvettes of the vermetid reef (Figs. 3, 4). Moreover, it has been observed that the stolons of *C. cylindracea* frequently grew strictly intermingled with the thalli of other macroalgae, leading to a complex web (Figs. 3, 4).

The alga was totally absent at Faraglione, Grotta Perciata, Pozzo and Stornello (Table 2). The abundance values of *C. cylindracea* were low and fell within the class 1 (cover <10%), with the exception of Punta Longa and San Giuseppe, where the abundances fell within the class 3 (cover <40% and >20%) (Table 2). At San Giuseppe, patches of *C. cylindracea* were more or less continuously present up to 1 m depth (Fig. 5) whereas at Cala Azzurra only isolated thalli were present beneath the reef. The macroalgal community inhabiting the cuvettes was dominated by the following five taxa: *Cystoseira amentacea* (C. Agardh) Bory, *Halopteris scoparia* (Linnaeus) Sauvageau, *Jania rubens* (Linnaeus) J.V. Lamouroux, *Laurencia obtusa* (Hudson) J.V. Lamouroux and *Padina pavonica* (Linnaeus) Thivy. No significant correlations were highlighted between the abundance values of *C. cylindracea* and those of the dominant macroalgae (Table 3).

Study area	*Reef pattern*	*2012*	*2015*
Faraglione	1	1	-
Pozzo	1	1	-
Arre Turino	3	-	1
Grotta Perciata	2	1	-
Stornello	2	1	-
Cala Rotonda	3	-	1
San Giuseppe	2	ms	3
San Nicola	1	ms	1
Cala Azzurra	2	ms	1
Punta Longa	2	ms	3

Table 2. Classes of abundance of *Caulerpa cylindracea* in 2012 and 2015 (ms = missing data, - = absent).

DISCUSSION AND CONCLUSIONS

Caulerpa cylindracea, the only alien species we recorded, was exclusively present within the cuvettes and generally showed a patchy distribution. Low abundance values were registered, with the exception of Punta Longa and San Giuseppe.

Asparagopsis taxiformis (Delile) Trevisan de Saint-Léon, observed in summer 2008 only at San Giuseppe within the cuvettes near the outer margin of the reef (Balistreri, 2009/2010; Fig. 6), was totally absent both in 2012 and 2015.

The comparison with data obtained from surveys carried out in 2012 highlighted some differences in the distribution of *C. cylindracea*. In particular, at Faraglione, Grotta Perciata, Pozzo and Stornello the alga, recorded in 2012, was totally absent in 2015 whereas at Arre Turino and Cala Rotonda it was absent in 2012 but was present in 2015 (Table 2). In both years low abundance values were registered.

At the moment the presence of *C. cylindracea* doesn't raise serious concern in the studied areas. However, as it is a highly successful species (Carruthers et al., 1993; Ceccherelli et al., 2000; Ceccherelli & Piazzi, 2001; Raniello et al., 2007; Occhipinti-Ambrogi et al., 2011; Felline et al., 2012; Gorbi et al., 2014) and MPAs seem to be not effective in protecting from the different threats and then from biological invasions, its spread and distribution should be regularly monitored. Moreover, since this species takes advantage of ecosystem degradation (Occhipinti-Ambrogi & Savini, 2003), making fragmented or less structured habitats highly vulnerable to its invasion (Ruitton et al.,

Taxa		Classes of abundance									
		Faraglione	Pozzo	Arre Turino	Grotta Perciata	Stornello	Cala Rotonda	San Giuseppe	San Nicola	Cala Azzurra	Punta Longa
R	*Jania rubens*	1	0	1	2	0	1	4	2	2	0
R	*Laurencia obtusa*	1	1	1	1	1	0	0	2	1	0
O	*Cystoseira amentacea*	4	4	3	4	4	4	2	0	3	3
O	*Halopteris scoparia*	0	0	1	0	0	0	2	2	0	0
O	*Padina pavonica*	0	1	3	1	0	0	1	1	0	0
C	*Caulerpa cylindracea*	0	0	1	0	0	1	3	1	1	3

Table 3. Classes of abundance of *Caulerpa cylindracea* and the dominant macroalgae in 2015 (R = Rhodophyta, O = Ochrophyta, C = Chlorophyta).

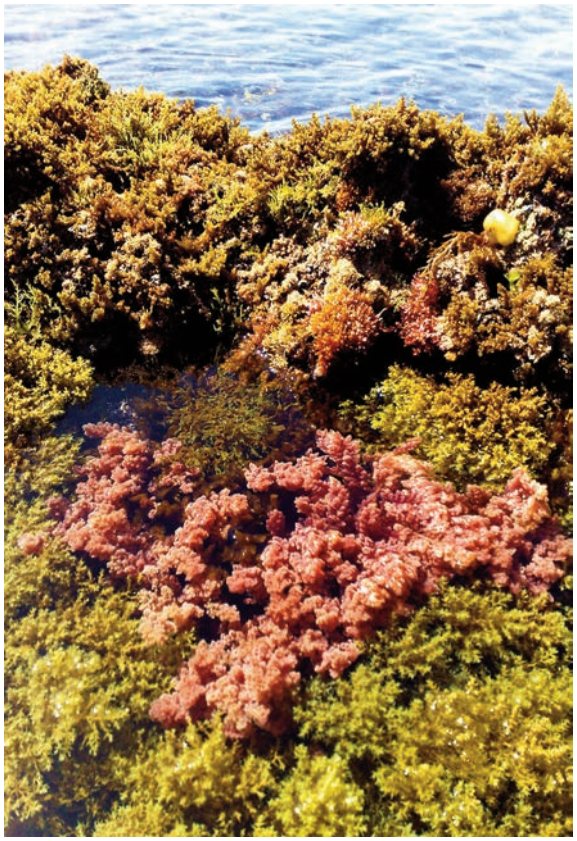


Figure 6. Thalli of *Asparagopsis taxiformis* (San Giuseppe).

2005; Bulleri et al., 2010, 2011; Katsanevakis et al., 2010), effective management and conservation strategies have to be planned within the MPA.

The vermetid reef is a highly vulnerable habitat, characterised by a delicate balance between two opposite processes, deposition and erosion, with the balance generally tilting toward deposition (Chemello & Silenzi, 2011), even though "*the structure can undergo a kind of 'suicide' leading to its destruction by catastrophic events*" (Antonioli et al., 1999; Chemello & Silenzi, 2011). Moreover, increases in sedimentation might enhance the invasiveness of alien species such as *C. cylindracea* (Airoldi & Cinelli, 1997; Piazzi et al., 2007). Indeed, this alga is able to tolerate high sedimentation rates and its spread and competitive ability may be enhanced by sediment deposition as consequence of its ability to trap sediments (Piazzi et al., 2005, 2007). As consequence of its active mechanism of stolonisation it forms compact multilayered mats together with macroalgae, that traps sediment creating a relevant decrease of redox potential underneath (Piazzi et al., 1997, 2005, 2007; Klein & Verlaque, 2008; Mannino & Di Giovanni, 2011; Matijević et al., 2013). This mat may negatively affect the benthic assemblages (in term of diversity and structure), alters sediment conditions, causes drastic reductions in diversity of the infaunal compartment

(Antolić et al., 2008; Klein & Verlaque, 2008; Baldacconi & Corriero, 2009; Holmer et al., 2009; Žuljević et al., 2011) and directly affect reproduction of demersal species (Felline et al., 2012).

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 biological marine invasions, regular monitoring programs, including public awareness campaigns (e.g. the project entitled "Progetto *Caulerpa cylindracea* - Egadi" sponsored by the Department of Biological Chemical and Pharmaceutical Sciences and Technologies, University of Palermo and the Egadi Islands MPA and available at http://www.ampisoleegadi.it/progetto_caulerpa_cylindracea_egadi.html), regular surveys and mapping by scientists, are strongly needed to assess the spread dynamics of invasive species not only within the protected areas (i.e. MPAs and Natural Reserves), but also in their surroundings in order to reduce continuous spillover effects (see also Otero et al., 2013). In the MPAs, high rates of visitation could promote the introduction of invasive species through increased disturbance and vectors (e.g., boat anchors, SCUBA equipment, bilge water, hull fouling) and subsequent dispersal of propagules (Minchinton & Bertness, 2003; West et al., 2007; Britton-Simmons & Abbott, 2008; Burfeind et al., 2013), therefore an Invasive Alien Species (IAS) strategy integrated into the management plan of the Egadi Islands MPA may be highly desirable.

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