



A new record of the invasive seaweed *Caulerpa cylindracea* Sonder in the South Adriatic Sea



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ABSTRACT

The green alga *Caulerpa cylindracea* Sonder is one of the most infamous and threatening invasive species in the Mediterranean Sea. Since 1985, it started rapidly spreading to all Mediterranean regions causing many ecological changes on natural communities. In the present study, we present an example of this proliferation with the first record in the Marine Protected Area of Tremiti Island (MPATI) in the South Adriatic Sea. Fifteen sites along the coast and 5 different depths have been investigated. Our results provide evidence of a wide invasion of this pest in three islands, San Domino, San Nicola and Capraia. This study fills a particular data gap in the ongoing bio-monitoring of invasive seaweeds in the Mediterranean Sea representing a base line of this invasive species for the MPATI.

1. Introduction

Ongoing climate change and impacts related to human population increases, including aquaculture, shipping and transportation are considered important driving forces behind the intensification of biological invasion phenomena worldwide (Strefaris et al., 2005; Occhipinti-Ambrogi, 2007; Schaffelke and Hewitt, 2007; Jauni et al., 2015). The scientific community has highlighted either positive, negligible and negative relationships between native biodiversity and invasions of exotic species (Lonsdale, 1999; McKinney and Lockwood, 1999; Byrnes et al., 2007; Fridley et al., 2007; Stachowicz et al., 2007; Wallentinus and Nyberg, 2007; Rilov and Crooks, 2009; Tamburello et al., 2015). It is however generally accepted that interactions between invasive species and native communities cause biotic and abiotic changes (Levine and D'Antonio, 1999; Ceccherelli and Sechi, 2002; Grosholz, 2002; Kennedy et al., 2002; Arenas et al., 2006; Beisner et al., 2006; Bulleri and Benedetti-Cecchi, 2008; Piazzini and Balata, 2009). Although invasive species affect marine ecosystems at the global scale, the Mediterranean Sea is amongst the most severely affected, with approximately 1000 introduced species, that now represent more than 5% of the known flora and fauna (Boudouresque et al., 2005; Occhipinti-Ambrogi and Shepard, 2007; Galil, 2008; Zenetos et al., 2012; Gorbi et al., 2014). There is

a pressing need to understand the mechanisms regulating species invasions both to predict pathways of invasion and to control their spread (Strefaris and Zenetos, 2006; Anderson, 2007; Gollasch et al., 2007; Hewitt and Campbell, 2007).

The alien green alga *Caulerpa cylindracea* Sonder is one of the most infamous and threatening invasive species in the Mediterranean Sea (Piazzini et al., 2005a,b; Montefalcone et al., 2015). This species was first found in the Mediterranean Sea along the Tunisia coast in 1985 (Sghaier et al., 2015), being introduced from south-western Australia (Famà et al., 2000; Verlaque et al., 2003; Belton et al., 2014). It was subsequently reported along the coastline of 12 Mediterranean countries. On the Italian coast, this species was first reported by Alongi et al. (1993), followed by the coasts of Greece (Panayotidis and Montesanto, 1994), Albania (Di Martino and Giaccone, 1995), Cyprus (Hadjichristophorou et al., 1997), France (Jousson et al., 1998), Spain (Ballesteros et al., 1999), Tunisia (Belkhiria, 1999), Turkey (Cirik, 1999), Malta (Stevens, 1999), Algeria (Verlaque et al., 2003; Ould-Ahmed and Meinesz, 2007), Croatia (Žuljević et al., 2003) and Montenegro (Mačić and Kaščelan 2006) also within many Marine Protected Areas (Katsanevakis et al., 2010; Felling et al., 2012). The species has been recorded on a variety of substrates and benthic assemblages, between 0 and 70 m depth, in both polluted and unpolluted areas, and proliferated rapidly showing high

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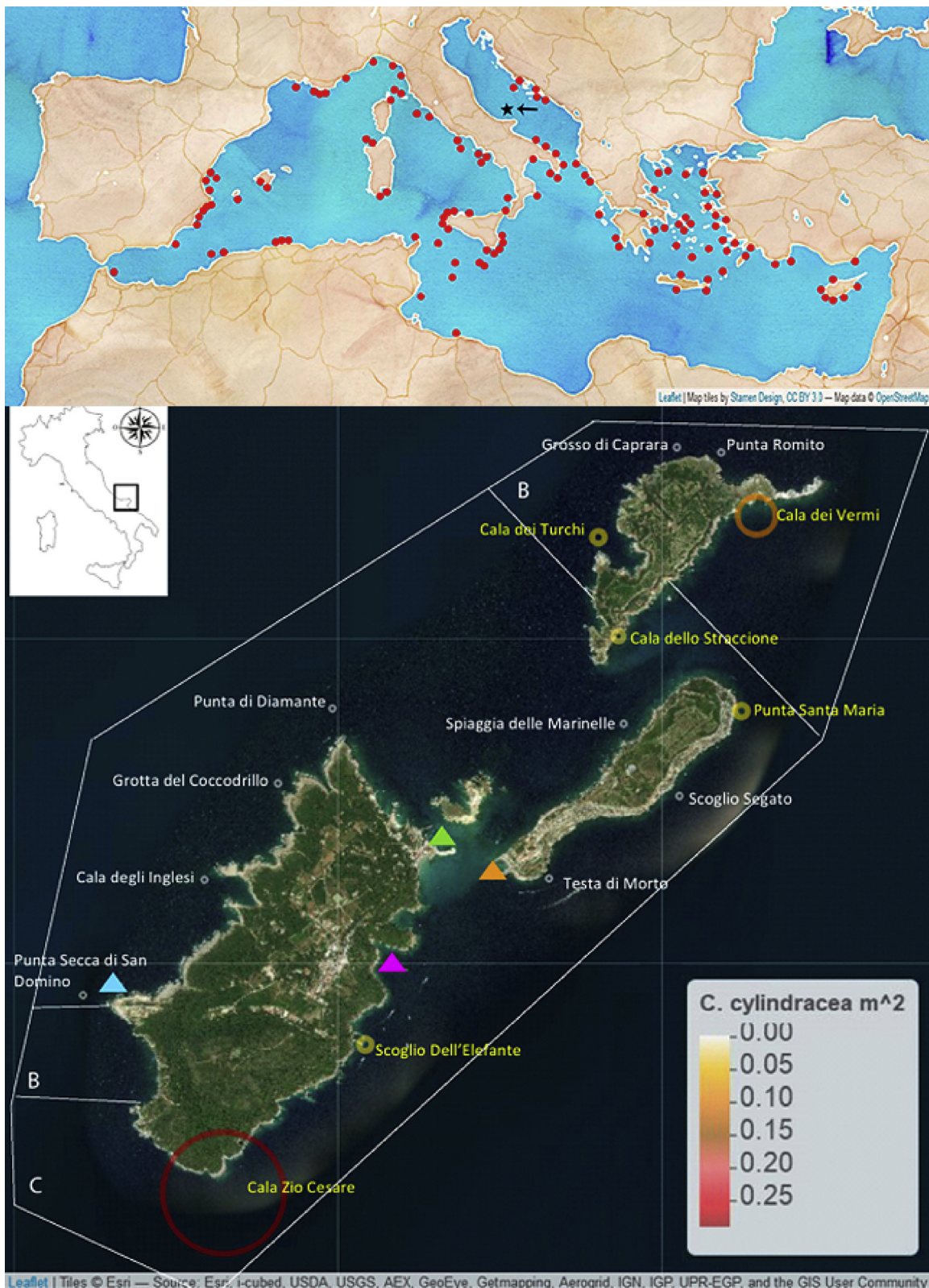


Fig. 1. a) Updated geographical distribution of *Caulerpa cylindracea* in the Mediterranean Sea. Black dots denote invaded locations cited in Verlaque et al., (2000); Ruiz et al., 2007; Sciberras and Schembri (2007); Klein and Verlaque (2008); Bouiadjra et al., (2010); Guillén et al., 2010; Rivera-Ingraham et al., (2010); Tsiamis et al., (2010); Bentaallah and Kerfouf (2013); Otero et al., (2013); Altamirano et al., (2014); star with black arrow indicates the new reported presence; b) Map of the MPA of Tremiti Islands with the 15 transects (7 labeled in yellow with presence of *C. cylindracea*; 8 labeled in white without); and the four alleged pollution sources; Gas station (sky blue triangle Site A); Port of San Domino (green triangle Site B); Port of San Nicola (orange triangle Site C); Water Tanker Vessel (fuchsia triangle Site D). The circle size and color refer to the cover of *C. cylindracea* as total sum in all quadrats and in all depths of the sites where it has been reported.

Table 1

Sites and number of visual quadrats where *C. cylindracea* was recorded for each island, site and depth. Only the quadrats with *C. cylindracea* are reported. The cover is reported as cumulative cover surface in m² and the biomass as cumulative sum of dry-weight biomass in g/m² for each depth.

Island	Site	Latitude	Longitude	Depth (m)	Quadrats	<i>C.cylindracea</i> (m ²)	dryweight(g /m ²)
SD	Cala Zio Cesare	42.10378° N	15.48297° E	5/10	0	0	0
				15	6	0.029	23,900
				20	10	0.101	68,200
				25	10	0.158	157,300
	Scoglio Dell'Elefante	42.11045° N	15.49262° E	5/10/15	0	0	0
				20	3	0.028	18,400
				25	0	0	0
	Punta Di Diamante	42.12730° N	15.49037° E	5/10/15/20/25	0	0	0
	Grotta Del Coccodrillo	42.12359° N	15.48668° E	5/10/15/20/25	0	0	0
	Cala Degli Inglesi	42.11872° N	15.48172° E	5/10/15/20/25	0	0	0
	Punta Secca Di San Domino	42.11291° N	15.47351° E	5/10	0	0	0
				15	3	0.003	2,500
				20/25	0	0	0
				20	0	0	0
	SN	Testa Di Morto	42.11877° N	15.50503° E	5/10/15/20/25	0	0
5/10/15/20/25					0	0	0
Scoglio Segato		42.12296° N	15.51393° E	5/10/15/20/25	0	0	0
				5/10/15	0	0	0
Punta Santa Maria		42.12720° N	15.51814° E	20	2	0.019	13,700
	25			3	0.012	9,400	
	25			0	0	0	
CA	Spiaggia Delle Marinelle	42.12655° N	15.51009° E	5/10/15/20	0	0	0
				5/10	0	0	0
	Cala Dello Straccione	42.13094° N	15.50980° E	15	4	0.025	27,100
				5	0	0	0
				10	1	0.005	3,000
				15	5	0.04	23,600
				20	4	0.021	13,100
	Cala Dei Vermi	42.13757° N	15.51910° E	25	2	0.027	18,600
				5/10/15/20/25	0	0	0
				5/10/15/20/25	0	0	0
	Punta Romito	42.14018° N	15.51670° E	5/10/15/20/25	0	0	0
	Grosso di Caprara	42.14044° N	15.51374° E	5/10/15/20/25	0	0	0
	Cala Dei Turchi	42.13593° N	15.50845° E	5/10/15	0	0	0
				20	4	0.031	32,000
				25	0	0	0
25				0	0	0	

Island	Site	Latitude	Longitude	Depth (m)	Quadrats	<i>C.cylindracea</i> (m ²)	dryweight(g /m ²)
SD	Cala Zio Cesare	42.10378° N	15.48297° E	5/10	0	0	0
				15	6	2.9 10 ⁻²	6 10 ⁻⁷
				20	10	0.1	1.7 10 ⁻⁶
				25	10	0.2	3.9 10 ⁻⁶
	Scoglio Dell'Elefante	42.11045° N	15.49262° E	5/10/15	0	0	0
				20	3	2.8 10 ⁻²	4.6 10 ⁻⁷
				25	0	0	0
	Punta Di Diamante	42.12730° N	15.49037° E	5/10/15/20/25	0	0	0
	Grotta Del Coccodrillo	42.12359° N	15.48668° E	5/10/15/20/25	0	0	0
	Cala Degli Inglesi	42.11872° N	15.48172° E	5/10/15/20/25	0	0	0
	Punta Secca Di San Domino	42.11291° N	15.47351° E	5/10	0	0	0
				15	3	2.7 10 ⁻³	6.3 10 ⁻⁸
				20 /25	0	0	0
				20	0	0	0
	SN	Testa Di Morto	42.11877° N	15.50503° E	5/10/15/20/25	0	0
5/10/15/20/25					0	0	0
Scoglio Segato		42.12296° N	15.51393° E	5/10/15/20/25	0	0	0
				5/10/15	0	0	0
Punta Santa Maria		42.12720° N	15.51814° E	20	2	1.9 10 ⁻²	3.4 10 ⁻⁷
	25			3	1.2 10 ⁻²	4.6 10 ⁻⁷	
	25			0	0	0	
CA	Spiaggia Delle Marinelle	42.12655° N	15.51009° E	5/10/15/20	0	0	0
				5/10	0	0	0
	Cala Dello Straccione	42.13094° N	15.50980° E	15	4	2.5 10 ⁻²	6.8 10 ⁻⁷
				5	0	0	0
				10	1	4.5 10 ⁻³	7.4 10 ⁻¹²
				15	5	4 10 ⁻²	5.9 10 ⁻⁷
				20	4	2.1 10 ⁻²	3.3 10 ⁻⁷
	Cala Dei Vermi	42.13757° N	15.51910° E	25	2	2.7 10 ⁻²	4.7 10 ⁻⁷
				5/10/15/20/25	0	0	0
				5/10/15/20/25	0	0	0
	Punta Romito	42.14018° N	15.51670° E	5/10/15/20/25	0	0	0
	Grosso di Caprara	42.14044° N	15.51374° E	5/10/15/20/25	0	0	0
	Cala Dei Turchi	42.13593° N	15.50845° E	5/10/15	0	0	0
				20	4	3.1 10 ⁻²	8 10 ⁻⁷
				25	0	0	0
25				0	0	0	

adaptability to physical stressors (Verlaque et al., 2000, 2003; Capiomont et al., 2005; Piazzini et al., 2005a,b; 2016; Streftaris and Zenetos, 2006; Tsiamis et al., 2008; Cebrian and Ballesteros, 2009; Piazzini and Balata, 2009; Altamirano et al., 2014; Bulleri and Malquori, 2015) displaying a maximum growth rate and yield at 27 °C and 25 °C, respectively, and maintaining an high eco-physiological rates between 25 °C and 29 °C (Sampeiro-Ramos et al., 2015). It can spread by fragmentation (Smith

and Walters, 1999) sexual reproduction (Panayotidis and Žuljević, 2001) and its spherical branchlets can also act as propagules (Renoncourt and Meinesz, 2002).

Caulerpa cylindracea exerts negative effects on marine macrophytes (Ceccherelli and Campo, 2002; Raniello et al., 2007), and can alter the behavior of native species, with putative adverse repercussions on patterns of fish growth and population dynamics (Magliozzi et al., 2017).

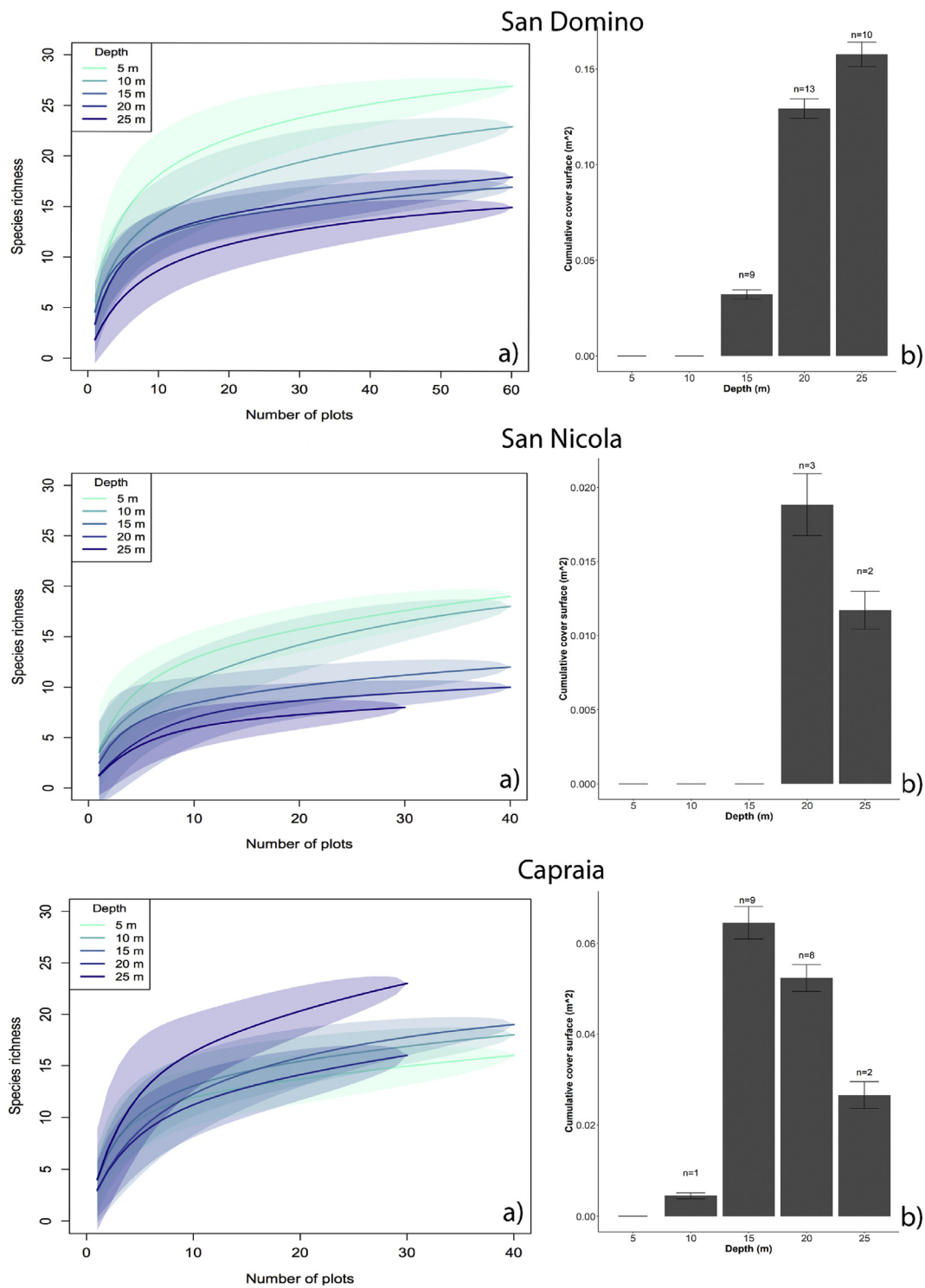


Fig. 2. a) Species accumulation curves and b) bar plots illustrating the abundance of *C. cylindracea* as cumulative cover and standard deviation in all quadrats where it was recorded, grouped by depth and isle; n = number of plots with *C. cylindracea*.

This seaweed can exert relevant effects on composition of sedimentary organic matter (OM), and on the associated microbial populations (Rizzo et al., 2017). There are other well documented negative implications; on alpha diversity of benthic assemblages (Piazzi et al., 2001; Balata et al., 2004; Piazzi and Balata, 2008; Pacciardi et al., 2011); on Carbon turnover in invaded sediments (Pusceddu et al., 2016); on native macroalgal assemblages (Piazzi and Ceccherelli, 2006); and on macrofauna (Lorenti et al., 2011; Cantasano et al., 2017) such as, amphipods (Vazquez-Luis et al., 2008). The aim of the present study is to report a new record of

Caulerpa cylindracea in the South Adriatic Sea reporting the magnitude of its invasion in the Marine Protected Area of Tremiti Island (MPATI).

2. Materials and methods

2.1. Sampling

The survey was conducted in the MPATI located in the southern Adriatic Sea (Figure 1a, b), founded in 1989. The MPATI is divided into

Table 2

Sampling sites in San Domino with depth (m); slope and type of substrate expressed as M = mixed; R = rock; S = sand; water temperature (C°); main wind, M = Maestrale (North-West) and S = Scirocco (South-East); presence (+) absence (-) of *C. cylindracea* (*C. cyl*) and mean species richness by depth and site.

San Domino									
Site	Depth (m)	Slope	Substrate (%)			T (C°)	Wind	C. cyl	S.R.
			M	R	S				
Cala Zio Cesare	5	L	–	20	80	26.1	S	–	4
	10	M	30	70	–	24.9	S	–	5
	15	H	50	40	10	23.5	S	+	5
	20	L	–	80	20	22.2	S	+	3
	25	L	10	80	10	21	S	+	4
Scoglio Dell'Elefante	5	H	–	100	–	26.6	S	–	4
	10	M	–	100	–	26.2	S	–	5
	15	M	–	90	10	25.6	S	–	4
	20	L	20	60	20	25.2	S	+	4
	25	L	40	–	60	24.7	S	–	1
Punta Di Diamante	5	M	–	100	–	26.8	M	–	6
	10	M	–	100	–	25	M	–	6
	15	M	–	100	–	23.3	M	–	5
	20	M	–	100	–	21.4	M	–	5
	25	L	60	–	40	18.5	M	–	3
Grotta Del Coccodrillo	5	L	–	100	–	28	M	–	6
	10	H	–	100	–	26.5	M	–	4
	15	H	–	100	–	25.3	M	–	5
	20	M	80	20	–	23.6	M	–	5
	25	L	20	20	60	22	M	–	3
Cala Degli Inglesi	5	L	–	100	–	28	M	–	6
	10	L	–	100	–	26.5	M	–	4
	15	L	–	100	–	25.3	M	–	5
	20	M	–	100	–	23.6	M	–	3
	25	M	–	40	60	22	M	–	2
Punta Secca Di San Domino	5	L	–	100	–	26.8	M	–	8
	10	H	20	80	–	24.6	M	–	5
	15	H	80	20	–	22.5	M	+	4
	20	H	30	40	30	20.3	M	–	4
	25	L	10	–	90	18.2	M	–	2

Table 3

Sampling sites in San Nicola with depth (m); slope and type of substrate expressed as M = mixed; R = rock; S = sand; water temperature (C°); main wind, M = Maestrale (North-West) and S = Scirocco (South-East); presence (+) absence (-) of *C. cylindracea* (*C. cyl*) and mean species richness by depth and site.

San Nicola									
Site	Depth (m)	Slope	Substrate (%)			T (C°)	Wind	C. cyl	S.R.
			M	R	S				
Testa Di Morto	5	M	–	100	–	26.8	S	–	6
	10	M	20	80	–	24.5	S	–	3
	15	M	30	60	10	22.2	S	–	4
	20	M	40	30	30	20	S	–	1
	25	M	20	20	60	17.8	S	–	0
Scoglio Segato	5	M	40	60	–	26.6	S	–	1
	10	M	10	80	10	24.8	S	–	4
	15	M	40	40	20	22.6	S	–	2
	20	M	20	20	60	20.8	S	–	1
	25	M	40	–	60	19.3	S	–	2
Punta Santa Maria	5	M	–	100	–	25.9	S	–	5
	10	M	–	100	–	24.7	S	–	4
	15	M	–	100	–	23.9	S	–	3
	20	M	20	40	40	23.1	S	+	2
	25	M	20	50	30	22.6	S	+	2
Spiaggia Delle Marinelle	5	M	–	100	–	26.5	M	–	4
	10	M	10	90	–	25.9	M	–	4
	15	L	100	–	–	25.4	M	–	1
	20	L	100	–	–	24.8	M	–	0

three main management zones (A, B, C). The A Zone is the no entry-no take area and only few scientific activities with specific authorizations are permitted. In the B Zone, anchoring, spearfishing and recreational fishing are forbidden. Scientific activities, navigation, diving and artisanal fishing are regulated by specific authorizations; swimming is permitted. In the C Zone, spearfishing is forbidden, artisanal fishing and scientific activities are regulated by authorizations. Navigation, swimming, anchoring, diving and recreational fishing are permitted.

Field work was conducted during August and September 2013. Five different depths (5, 10, 15, 20, and 25 m) were sampled at 15 sites along the coast of the three islands of MPATI (San Domino, San Nicola, and Capraia) by SCUBA diving. At each depth, 10 random quadrats $20 \times 20 \text{ cm}^2$ were photographically sampled using a Canon G11 (CanonG11) (Klein and Verlaque, 2008; Baldaconi and Corriero, 2009; Katsanevakis et al., 2010; Cantasano et al., 2017). A total of 730 photos (in San Nicola all 5 depths are not present, see Table 1 and Fig. 2) were taken. Wherever

Table 4

Sampling sites in Capraia with depth (m); slope and type of substrate expressed as M = mixed; R = rock; S = sand; water temperature (C°); main wind, M = Maestrале (North-West) and S = Scirocco (South-East); presence (+) absence (-) of *C. cylindracea* (*C. cyl*) and mean species richness by depth and site.

Capraia									
Site	Depth (m)	Slope	Substrate (%)			T (C°)	Wind	C. cyl	S.R.
			M	R	S				
Cala Dello Straccione	5	L	-	100	-	26.8	S	-	5
	10	L	10	90	-	25	S	-	6
	15	L	50	20	30	24	S	+	3
Cala Dei Vermi	5	M	-	100	-	26.5	S	-	4
	10	M	90	-	10	25.1	S	+	2
	15	L	100	-	-	24	S	+	2
	20	L	40	-	60	22.8	S	+	2
Punta Romito	25	L	-	-	100	21.6	S	+	2
	5	H	-	100	-	26.2	M	-	4
	10	H	-	100	-	24	M	-	4
	15	H	-	100	-	22.2	M	-	4
	20	M	-	100	-	20.5	M	-	5
Grosso di Caprara	25	M	-	100	-	18.6	M	-	7
	5	H	-	100	-	26.4	M	-	4
	10	H	-	100	-	23.6	M	-	5
	15	H	-	100	-	22	M	-	5
	20	M	-	100	-	20.2	M	-	4
Cala Dei Turchi	25	M	-	100	-	18.4	M	-	4
	5	L	-	100	-	26	M	-	4
	10	H	-	100	-	24.2	M	-	5
	15	H	-	100	-	22.5	M	-	5
	20	L	40	60	-	20.5	M	+	4
25	L	30	70	-	18.8	M	-	4	

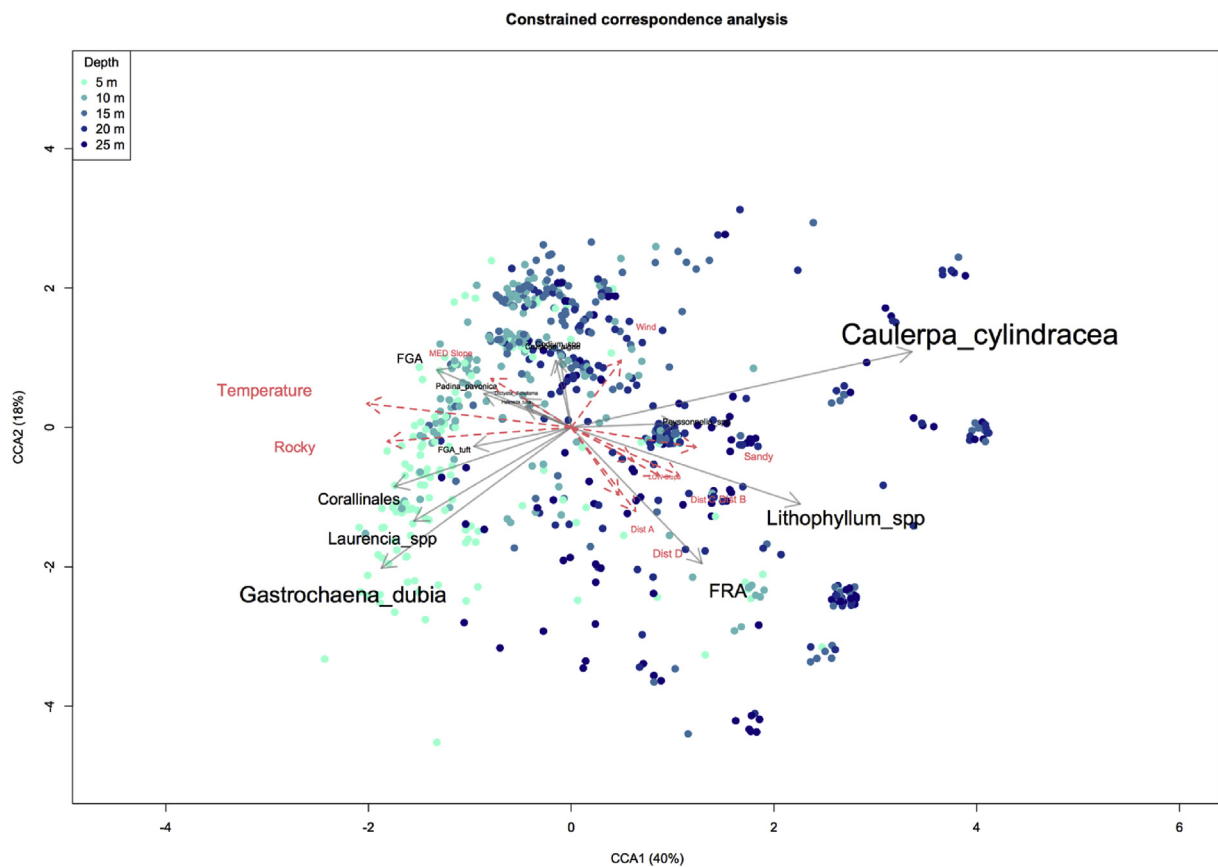


Fig. 3. Constrained correspondence analysis (CCA) on fauna and flora P/A data collected at Capraia, San Domino and San Nicola from 5, 10, 15, 20 and 25 m depth. Species vectors are indicated in grey, and species names in black. Environmental variables vectors and names are shown in red. Each point refers to a single replicate quadrat.

present, thalli of *C. cylindracea* were scraped off from each quadrat and stored in individual plastic bags. Seawater temperature, seafloor slope and substrate main features were recorded (Tables 2, 3, and 4).

2.2. Data analyses

Presence/absence (P/A) of fauna and flora were recorded at the taxa level for all photos. *Caulerpa cylindracea* percentage cover was estimated with image analysis by Photoshop and SeaScape software. The sampled algae were dried and then weighed. Dry weight was obtained after drying at 60 °C to constant weight. Wind exposure was recorded as mean wind affecting each individual site. As corroborated by the frequency and velocity data gathered by the airport of Foggia-Gino Lisa (Foggia-Gino Lisa), the primary winds blowing across the study area are: Scirocco (South-East) and Maestrale (North-West). The wind direction was associated to each study site based on the site's exposure. The distance of each site from four alleged pollution sources: Gas Port of San Domino, Port of San Nicola, Water Tanker Vessel (Fig. 1b), was calculated as shortest path along the coastline separating the two. Data were analyzed using a constrained correspondence analysis CCA. All data used for this study are provided in Supplementary Tables 1, 2, and 3.

3. Results

Our results show a predominance invasion along the south west coasts of the three islands with a peak of *C. cylindracea* in Cala Zio Cesare (Figs. 1 and 2 and Table 1). The invasion was recorded in all the three islands (3 sites in San Domino, 1 in San Nicola and 3 in Capraia. Fig. 1b) and in all the five sampling depths except at 5 m (Fig. 1b and Tables 1 and 4). Fifty-seven quadrats reported the presence of *C. cylindracea* (Tables 1, 2, 3, and 4; Fig. 1b) with a cumulative cover surface of 0.5 m² and a cumulative sum of dry-weight biomass of 1.10⁻⁵ g/m² for a sampling surface of 2.3 m², representing a percentage cover of 22%. The most invaded depths were 15, 20 and 25 m. At 15 m depth we reported a wide range of cumulative cover and cumulative sum of dry-weight biomass from only 2.7.10⁻³ m² and 6.3.10⁻⁸ g/m² in Punta Secca di San Domino (Isle of San Domino) to 4.10⁻² m² and 5.9.10⁻⁷ g/m² in Cala dei Vermi (Isle of Capraia). The highest cover and biomass were collected in Cala Zio Cesare at 25 m depth, where all the 10 random quadrats presented *C. cylindracea* with a cumulative cover of 0.2 m² and a cumulative sum of dry-weight biomass of 3.9.10⁻⁶ g/m². However, only in Cala dei Vermi (Isle of Capraia), *C. cylindracea* was recorded at all depths except at 5 m (Fig. 1b and Tables 1 and 4). During the sampling, seawater temperature at the five depths ranged between 18 °C (at 25 m of Punta Secca di San Domino, where the lowest abundance was recorded) and 27 °C (at 5 m in Cala Degli Inglesi, where the species was absent).

Species accumulation curves were also produced for each depth, separately for each island. A different pattern emerges in Capraia compared to the other islands (Fig. 2). CCA has been performed on fauna and flora P/A data collected at Capraia, San Domino and San Nicola from 5, 10, 15, 20 and 25 m depth. In CCA1 the explained variability is 40% and for CCA2 is 18% (Fig. 3).

4. Discussion

Although, the effect of water motion on this species is unclear and it has been found on exposed shores as well as in sheltered areas (Klein and Verlaque, 2008), *C. cylindracea* was recorded mostly in sites protected from the main wind, Maestrale (from North West): in 5 out of 7 sheltered sites and in only 2 out of 8 exposed sites (Fig. 1). Our results show two interesting patterns: i) San Domino and San Nicola similarly display a higher species richness (SR) at lower depths (5 and 10 m) where *C. cylindracea* was not recorded (Fig. 2); ii) by contrast, the island of Capraia, where *C. cylindracea* invaded four out of the five investigated depths (10, 15, 20 and 25 m), shows a higher SR distribution at 25 m (Bar plots in Fig. 2). Similar patterns of colonization are reported by Cebrian

and Ballesteros (2009) in the Archipelago of Cabrera National Park (Western Mediterranean). Our results show a lower SR in shallow water (5–20 m) associated with presence of *C. cylindracea* as similarly reported by Piazzini and Balata (2008) on the rocky coast of Tuscany (north-western Mediterranean Sea). Also Baldaconi and Corriero (2009) report a concomitant significant decrease in sponge structure community and cover caused by the spread of *C. cylindracea* in a nearby area along Apulia coast. In a close area, along the Calbiran Tyrrhenian coasts Cantasano et al. (2017) report as well a gradual decrease of crustose species directly associated with the presence of *C. cylindracea*.

Contrarily to what reported by Mifsud and Lanfranco (2007), the CCA analysis (Fig. 3) illustrates a low sensitivity to the four anthropic alleged pollution sources (Fig. 2b) and to the seafloor slope. These variables exert a low relevance in the dynamics of this invasive species, while conversely, temperature and type of substrate exert a larger effect, confirming the role of seawater temperature increase in the Mediterranean on the spread of this alga (Argyrou et al., 1999; Ruitton et al., 2005b; Ivesa et al., 2015). Interestingly, although dead mat of the seagrass *Posidonia oceanica* and rock covered with photophilic algae are often reported as favorable substrates for the spread of this alga (Piazzini and Cinelli, 1999; Piazzini et al., 2001; Ceccherelli et al., 2002; Piazzini et al., 2003; Ruitton et al., 2005a, b; Bulleri and Benedetti-Cecchi, 2008; Katsanevakis et al., 2010; Infantes et al., 2011), in the study area a larger abundance on sand and detrital substrata was recorded (Tables 2, 3, and 4). It is consistent with a recent review by Sghaier et al. (2015) along the coast of Tunisia, who report a higher presence of *C. cylindracea* on sand substrata instead of rock and *P. oceanica* meadow (0.68 % of sites observed). By contrast, Piazzini and Cinelli (1999) and Infantes et al. (2011) show a high density of *C. cylindracea* in shallow waters 0–3 m and <8 m depth, respectively. Moreover, De Biasi et al. (1999) observed a decrease in the *C. cylindracea* cover from 5–10 m to 15–20 m depth in a different pattern to that reported in MPATI.

Although, many studies show clear effects of this seaweed on benthic communities, and a recent review of Piazzini et al. (2016) underlines ten main direct and indirect factors affecting the spread of this species, many others are still poorly known. For example, the relevance of depth, water movement, herbivores and other invaders in dispersal dynamic of this pest are still not clear. Comparing our data with other studies available from *C. cylindracea* populations observed in different nearby areas and depths of the Mediterranean Sea, no general patterns can be clearly defined. However, as for *C. taxifolia* (Boudouresque and Verlaque, 2012) also for *C. cylindracea* the invasion might be summarized in four main steps: (1) arrival, (2) settlement, (3) expansion, (4) persistence. The expansion process can be very long (Montefalcone et al., 2015; Ivesa et al., 2015) showing that only with long-term monitoring studies coupled with a better ecophysiological knowledge of *C. cylindracea* and through manipulative experiments, it could be possible to better understand key factors driving the invasion of this species in the Mediterranean Sea.

This first record shows a remarkable presence and distribution of this invasive alien species in the MPATI in different areas, depths and substrates. Additional studies of particular biological interest are necessary to evaluate the spread, invasion speed, and impact of this seaweed. Further monitoring activities will thus improve actual knowledge about the interaction of this seaweed with native Mediterranean communities.

Declarations

Author contribution statement

Andrea Pierucci: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Gina De La Fuente: Performed the experiments; Contributed reagents, materials, analysis tools or data.

Rita Cannas, Mariachiara Chiantore: Contributed reagents, materials,

analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

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References

- Alongi, G., Cormaci, M., Furnari, G., Giaccone, G., 1993. Prima segnalazione di *Caulerpa racemosa* (Chlorophyceae, Caulerpales) per le coste italiane. *Bollettino dell'Accademia Gioenia di Scienze Naturali Catania* 26 (342), 9–53.
- Altamirano, M., Andreakis, N., Souza-Egipsy, V., Zanolli, M., De la Rosa, J., 2014. First record of *Caulerpa cylindracea* (caulerpales, chlorophyta) in andalusia (southern Spain). In: *Anales del Jardín Botánico de Madrid*, 71, pp. 2–007.
- Anderson, L.W., 2007. Control of invasive seaweeds. *Bot. Mar.* 50, 418–437.
- Arenas, F., Sanchez, I., Hawkins, S., Jenkins, S.R., 2006. The invasibility of marine algal assemblages: role of functional diversity and identity. *Ecology* 87, 2851–2861.
- Argyrou, M., Demetropoulos, A., Hadjichristophorou, M., 1999. Expansion of the macroalga *Caulerpa racemosa* and changes in softbottom macrofaunal assemblages in Moni Bay, Cyprus. *Oceanol. Acta* 22, 517–528.
- Balata, D., Piazzì, L., Cinelli, F., 2004. A comparison among macroalgal assemblages in areas invaded by *Caulerpa taxifolia* and *C. racemosa* on subtidal Mediterranean reefs. *PSZNI Marine Ecol.* 25, 1–13.
- Baldacconi, R., Corriero, G., 2009. Effects of the spread of the alga *Caulerpa racemosa* var. *cylindracea* on the sponge assemblage from coralligenous concretions of the Apulian coast (Ionian Sea, Italy). *Mar. Ecol. Prog. Ser.* 307, 337–345.
- Ballesteros, E., Grau, M., Riera, F., 1999. *Caulerpa racemosa* (forsskål) J. Agardh (caulerpales, chlorophyta) a mallorca. *Bolleti Soc. Historia Nat.s Balears* 42, 68.
- Beisner, B.E., Hovius, J., Hayward, A., Kolasa, J., Romanuk, T.N., 2006. Environmental productivity and biodiversity effects on invertebrate community invisibility. *Biol. Invasions* 8, 655–664.
- Belkhiria, S., 1999. Tunisia. In: United Nations Environment Programme (Ed.), *Proceedings of the Workshop on Invasive Caulerpa Species in the Mediterranean*, 125. MAP Technical Report Series, pp. 295–296.
- Belton, G.S., Prud'homme van Reine, W.F., Huisman, J.M., Draisma, S.G.A., Gurgel, C.F.D., 2014. Resolving phenotypic plasticity and species designation in the morphologically challenging *Caulerpa racemosa-peltata* complex (Chlorophyta, Caulerpales). *J. Phycol.* 50 (1), 32–54.
- Bentaallah, M.E.A., Kerfouf, A., 2013. Prolifération de l'algue *Caulerpa racemosa* dans les écosystèmes littoraux de l'Algérie: état des lieux et des connaissances. *Physio-Géo. Géographie physique et environnement* 7, 157–164.
- Boudouresque, C.F., Verlaque, M., 2012. An overview of species introduction and invasion processes in marine and coastal lagoon habitats. *Cah. Biol. Mar.* 53, 309–317.
- Boudouresque, C.F., Ruitton, S., Verlaque, M., 2005. Large-scale disturbances, regime shift and recovery in littoral systems subject to biological invasions. In: Velikova, V., Chipev, N. (Eds.), *Large-scale Disturbances (Regime Shifts) and Recovery in Aquatic Ecosystems: Challenges for Management towards Sustainability*. UNESCO 85–101.
- Bouiadjra, B.B., Taleb, M.Z., Marouf, A., Benkada, M.Y., Riadi, H., 2010. First record of the invasive alga *Caulerpa racemosa* (caulerpales, chlorophyta) in the gulf of arzew (western Algeria). *Aquat. Invasions* 5, 97–101.
- Bulleri, F., Benedetti-Cecchi, L., 2008. Facilitation of the introduced green alga *Caulerpa racemosa* by resident algal turfs: experimental evaluation of underlying mechanisms. *Mar. Ecol. Prog. Ser.* 364, 77–86.
- Bulleri, F., Malquori, F., 2015. High tolerance to simulated herbivory in the clonal seaweed, *Caulerpa cylindracea*. *Mar. Environ. Res.* 107, 61–65.
- Byrnes, J.E., Reynolds, P.L., Stachowicz, J.J., 2007. Invasions and extinctions reshape coastal marine food webs. *PLoS One* 3, 295.
- CanonG11 <https://www.usa.canon.com/internet/portal/us/home/support/details/camera/support-point-and-shoot/powershot-g-series/powershot-g11/powershot-g11>.
- Cantasano, N., Pellicone, G., Di Martino, V., 2017. The spread of *Caulerpa cylindracea* in Calabria (Italy) and the effects of shipping activities. *Ocean Coast Manag.* 144, 51–58.
- Capiomont, A., Breugnot, E., den Haan, M., Meinesz, A., 2005. Phenology of a deep-water population of *Caulerpa racemosa* var. *cylindracea* in the Northwestern Mediterranean Sea. *Bot. Mar.* 48, 80–83.
- Cebrian, E., Ballesteros, E., 2009. Temporal and spatial variability in shallow and deep water populations of the invasive *Caulerpa racemosa* var. *cylindracea* in the Western Mediterranean. *Estuar. Coast Shelf Sci.* 83, 469–474.
- Ceccherelli, G., Campo, D., 2002. Different effects of *Caulerpa racemosa* on two co-occurring seagrasses in the Mediterranean. *Bot. Mar.* 45, 71–76.
- Ceccherelli, G., Sechi, N., 2002. Nutrient availability in the sediment and the reciprocal effects between the native seagrass *Cymodocea nodosa* and the introduced green alga *Caulerpa taxifolia* in a Mediterranean bay. *Hydrobiologia* 474, 57–66.
- Ceccherelli, G., Piazzì, L., Balata, D., 2002. Spread of introduced *Caulerpa* species in macroalgal habitats. *J. Exp. Mar. Biol. Ecol.* 280, 1–11.
- Cirik, S., 1999. Turquie. In: United Nations Environment Programme (Ed.), *Proceedings of the Workshop on Invasive Caulerpa Species in the Mediterranean*, 125. MAP Technical Report Series, pp. 299–300.
- De Biasi, A.M., Gai, F., Vannucci, A., 1999. Biologia delle Secche della Meloria: considerazioni sull'ecologia di *Caulerpa racemosa* (Forsskål) J. Agardh. *Biol. Mar. Mediterr.* 6 (1), 376–379.
- Di Martino, V., Giaccone, G., 1995. La dispersione in Mediterraneo di alghe tropicali del genere *Caulerpa*. *Bollettino dell'Accademia Gioenia di Scienze Naturali Catania* 28 (349), 693–705.
- Famá, P., Olsen, J.L., Stam, W.T., Procaccini, G., 2000. High levels of intra-and inter-individual polymorphism in the rDNA ITS1 of *Caulerpa racemosa* (Chlorophyta). *Eur. J. Phycol.* 35 (4), 349–356.
- Felline, S., Caricato, R., Cutignano, A., Gorbi, S., Lionetto, M.G., Mollo, E., Regoli, F., Terlizzi, A., 2012. Subtle effects of biological invasion. Cellular and physiological responses of fish eating the exotic pest *Caulerpa racemosa*. *PLoS One* 7 (6), e38763.
- Foggia-Ginosa Lisa. <http://www.meteo-allerta.it/it/europa/italia/meteo-foggia-gino-lisa/details/S162611/>.
- Fridley, J.D., Stachowicz, J.J., Naeem, S., Sax, D.F., Seabloom, E.W., Smith, M.D., Stohlgren, T.J., Tilman, D., Von Holle, B., 2007. The invasion paradox: reconciling pattern and process in species invasions. *Ecology* 8, 3–17.
- Gailil, B.S., 2008. Alien species in the Mediterranean Sea which, when, where, why? *Hydrobiologia* 606: 105–116 Gollasch S (2007) International collaboration on marine bioinvasions: the ICES response. *Mar. Pollut. Bull.* 55, 353–359.
- Gollasch, S., David, M., Voigt, M., Dragsund, E., Hewitt, C., Fukuyo, Y., 2007. Critical review of the IMO international convention on the management of ships' ballast water and sediments. *Harmful Algae* 6 (4), 585–600.
- Gorbi, S., Giuliani, M.E., Pittura, L., d'Errico, G., Terlizzi, A., Felline, S., Grauso, L., Mollo, E., Cutignano, A., Regoli, F., 2014. Could molecular effects of *Caulerpa racemosa* metabolites modulate the impact on fish populations of *Diplodus sargus*? *Mar. Environ. Res.* 96, 2–11.
- Grosholz, E., 2002. Ecological and evolutionary consequences of coastal invasions. *Trends Ecol. Evol.* 17, 22–27.
- Guillén, J., Jiménez, S., Martínez, J., Triviño, A., Múgica, Y., Argilés, J., Bueno, M., 2010. Expansion of the invasive algae *Caulerpa racemosa* var. *cylindracea* (Sonder) Verlaque, Huisman & Boudouresque, 2003 on the region of Valencia seabed. *Thalassas* 26, 135–149.
- Hadjichristophorou, M., Argyrou, M., Demetropoulos, A., Bianchi, T.S., 1997. A species list of the sublittoral soft-bottom macrobenthos of Cyprus. *Acta Adriat.* 38 (1), 3–32.
- Hewitt, C.L., Campbell, M.L., 2007. Mechanisms for the prevention of marine bioinvasions for better biosecurity. *Mar. Pollut. Bull.* 55, 395–401.
- Infantes, E., Terrados, J., Orfila, A., 2011. Assessment of substratum effect on the distribution of two invasive *Caulerpa* (Chlorophyta) species. *Estuar. Coast Shelf Sci.* 91, 434–444.
- Ivesa, L., Djakovac, T., Devescovi, M., 2015. Spreading patterns of the invasive *Caulerpa cylindracea* Sonder along the west istrian coast (northern Adriatic Sea, Croatia). *Mar. Environ. Res.* 107, 1–7.
- Jauni, M., Gripenberg, S., Ramula, S., 2015. Non-native plant species benefit from disturbance: a meta-analysis. *Oikos* 124, 122–129.
- Jousson, O., Pawlowski, J., Zaninetti, L., Meinesz, A., Boudouresque, C.F., 1998. Molecular evidence for the aquarium origin of the green alga *Caulerpa taxifolia* introduced to the Mediterranean Sea. *Mar. Ecol. Prog. Ser.* 172, 275–280.
- Katsanevakis, S., Issaris, Y., Poursanidis, D., Theosalou-Legaki, M., 2010. Vulnerability of marine habitats to the invasive green alga *Caulerpa racemosa* var. *cylindracea* within a marine protected area. *Mar. Environ. Res.* 70, 210–218.
- Kennedy, T.A., Naeem, S., Howe, K.M., Knops, J.M.H., Tilman, D., Reich, P., 2002. Biodiversity as a barrier to ecological invasion. *Nature* 417, 636–638.
- Klein, J., Verlaque, M., 2008. The *Caulerpa racemosa* invasion: a critical review. *Mar. Pollut. Bull.* 56, 205–225.
- Levine, J.M., D'Antonio, C.M., 1999. Elton revisited: a review of evidence linking diversity and invasibility. *Oikos* 87, 15–26.
- Lonsdale, W.M., 1999. Global patterns of plant invasions and the concept of invasibility. *Ecology* 80, 1522–1536.
- Lorenti, M., Gambi, M.C., Guglielmo, R., Patti, F.P., Scipione, M.B., Zupo, V., Buia, M.C., 2011. Soft-bottom macrofaunal assemblages in the Gulf of Salerno, Tyrrhenian Sea,

- Italy, an area affected by the invasion of the seaweed *Caulerpa racemosa* var. *cylindracea*. *Mar. Ecol. Evol. Perspect.* 32, 320–334.
- Mačić, V., Kaščelan, S., 2006. *Caulerpa racemosa* on the montenegrin coast. *Rapp. Comm. Int. Mer. Médit.* 38, 533.
- Magliozzi, L., Almada, F., Robalo, J., Mollo, E., Polese, G., Gonçalves, E.J., Felline, S., Terlizzi, A., D'Aniello, B., 2017. Cryptic effects of biological invasions: reduction of the aggressive behaviour of a native fish under the influence of an "invasive" biomolecule. *PLoS One* 12 (9), 0185620.
- McKinney, M.L., Lockwood, J.L., 1999. Biotic homogenization: a few winners replacing many losers in the next mass extinction. *Trends Ecol. Evol.* 14, 450–453.
- Mifsud, C., Lanfranco, E., 2007. *Caulerpa racemosa* (chlorophyta, caulerpales) in the Maltese islands (central mediterranean). In: Proceedings of the 3rd Mediterranean Symposium on Marine Vegetation, Marseille, France, pp. 27–29.
- Montefalcone, M., Morri, C., Parravicini, V., Bianchi, C.N., 2015. A tale of two invaders: divergent spreading kinetics of the alien green algae *Caulerpa taxifolia* and *Caulerpa cylindracea*. *Biol. Invasions* 17, 2717–2728.
- Occhipinti-Ambrogi, A., 2007. Global change and marine communities: alien species and climate change. *Mar. Pollut. Bull.* 55, 342–352.
- Occhipinti-Ambrogi, A., Sheppard, C., 2007. Special Issue: marine bioinvasions: a collection of reviews. *Mar. Pollut. Bull.* 55 (7/9), 299–401.
- 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, p. 136.
- Ould-Ahmed, N., Meinesz, A., 2007. First record of the invasive alga *Caulerpa racemosa* on the coast of Algeria. *Cryptogam. Algol.* 28 (3), 303–305.
- Pacciardi, L., De Biasi, A.M., Piazzzi, L., 2011. Effects of *Caulerpa racemosa* invasion on soft-bottom assemblages in the western Mediterranean Sea. *Biol. Invasions* 13 (12), 2677–2690.
- Panayotidis, P., Montesanto, B., 1994. *Caulerpa racemosa* (Chlorophyta) on the Greek coasts. *Cryptogam. Algol.* 15, 159–161.
- Panayotidis, P., Žuljević, A., 2001. Sexual reproduction of the invasive green alga *Caulerpa racemosa* var. *occidentalis* in the Mediterranean Sea. *Oceanol. Acta* 24 (2), 199–203.
- Piazzzi, L., Balata, D., 2008. The spread of *Caulerpa racemosa* var. *cylindracea* in the Mediterranean Sea: an example of how biological invasions can influence beta diversity. *Mar. Environ. Res.* 65, 50–61.
- Piazzzi, L., Balata, D., 2009. Invasion of alien macroalgae in different Mediterranean habitats. *Biol. Invasions* 11, 193–204.
- Piazzzi, L., Ceccherelli, G., 2006. Persistence of biological invasion effects: recovery of macroalgal assemblages after removal of *Caulerpa racemosa* var. *cylindracea*. *Estuar. Coastal Shelf Sci.* 68, 455–461.
- Piazzzi, L., Cinelli, F., 1999. Developpement et dynamique saisonniere d'un peuplement mediterraneen de l'algue tropicale *Caulerpa racemosa* (Forsskal). *J. Agardh. Cryptogamie. Algologie* 20, 295–300 (in French, with English Abstract).
- Piazzzi, L., Ceccherelli, G., Cinelli, F., 2001. Threat to macroalgal diversity: effects of the introduced green alga *Caulerpa racemosa* in the Mediterranean. *Mar. Ecol. Prog. Ser.* 210, 149–159.
- Piazzzi, L., Ceccherelli, G., Balata, D., Cinelli, F., 2003. Early patterns of *Caulerpa racemosa* recovery in the Mediterranean Sea: the influence of algal turfs. *J. Mar. Biol. Assoc. U. K.* 83, 27–29.
- Piazzzi, L., Balata, D., Ceccherelli, G., Cinelli, F., 2005a. Interactive effect of sedimentation and *Caulerpa racemosa* var. *cylindracea* invasion on macroalgal assemblages in the Mediterranean Sea. *Estuarine. Coastal Shelf Sci.* 64, 467–474.
- Piazzzi, L., Meinesz, A., Verlaque, M., Akčali, B., Antolić, B., Argyrou, M., Balata, D., Ballesteros, E., Calvo, S., Cinelli, F., Ćirik, S., Cossu, A., D'Archino, R., Djellouli, S.A., Javel, F., Lanfranco, E., Mifsud, C., Pala, D., Panayotidis, P., Peirano, A., Pergent, G., Petrocelli, A., Ruiynton, S., Žuljević, A., Ceccherelli, G., 2005b. Invasion of *Caulerpa racemosa* var. *cylindracea* (Caulerpales, Chlorophyta) in the Mediterranean Sea: an assessment of the early stages of spread. *Cryptogam. Algol.* 26, 189–202.
- Piazzzi, L., Balata, D., Bulleri, F., Gennaro, P., Ceccherelli, G., 2016. The invasion of *Caulerpa cylindracea* in the Mediterranean: the known, the unknown and the knowable. *Mar. Biol.* 163 (7), 161.
- Pusccheddu, A., Fraschetti, S., Scopa, M., Rizzo, L., Danovaro, R., 2016. Meiofauna communities, nematode diversity and C degradation rates in seagrass (*Posidonia oceanica* L.) and unvegetated sediments invaded by the algae *Caulerpa cylindracea* (Sonder). *Mar. Environ. Res.* 119, 88–99.
- Raniello, R., Mollo, E., Lorenti, M., Gavagnin, M., Buia, M.C., 2007. Phytotoxic activity of caulerpene from the Mediterranean invasive variety of *Caulerpa racemosa*: a potential allelochemical. *Biol. Invasions* 9 (4), 361–368.
- Renoncourt, L., Meinesz, A., 2002. Formation of propagules on an invasive strain of *Caulerpa racemosa* (chlorophyta) in the Mediterranean Sea. *Phycologia* 41, 533–535.
- Rilov, G., Crooks, J.A., 2009. Biological Invasions in Marine Ecosystems: Ecological, Management, and Geographic Perspectives, 30. Springer-Verlag, Herdelberg, 514–514.
- Rivera-Ingraham, G.A., García-Gómez, J.C., Espinosa, F., 2010. Presence of *Caulerpa racemosa* (forsskal) J. Agardh in ceuta (northern africa, Gibraltar area). *Biol. Invasions* 12, 1465–1466.
- Rizzo, L., Pusccheddu, A., Stabili, L., Alifano, P., Fraschetti, S., 2017. Potential effects of an invasive seaweed (*Caulerpa cylindracea*, Sonder) on sedimentary organic matter and microbial metabolic activities. *Sci. Rep.* 7 (1), 12113.
- Ruitton, S., Javel, F., Culioli, J.M., Meinesz, A., Pergent, G., Verlaque, M., 2005a. First assessment of the *Caulerpa racemosa* (caulerpales, chlorophyta) invasion along the French mediterranean coast. *Mar. Pollut. Bull.* 50, 1061–1068.
- Ruitton, S., Verlaque, M., Boudouresque, C.F., 2005b. Seasonal changes of the introduced *Caulerpa racemosa* var. *cylindracea* (Caulerpales, Chlorophyta) at the northwest limit of its Mediterranean range. *Aquat. Bot.* 82, 55–70.
- Ruíz, J.M., Ramos, A., García, R., 2007. Informe sobre la presencia del alga tropical invasora *Caulerpa racemosa* en el litoral murciano en 2006. Instituto Español de Oceanografía, Biblioteca del Centro Oceanográfico de Murcia, Spain.
- Sampeiro-Ramos, G., Olsen, Y., Tomas Marbà, N., 2015. Ecophysiological responses of three Mediterranean invasive seaweeds (*Acrothamnion preissii*, *Lophocladia lallemandii* and *Caulerpa cylindracea*) to experimental warming. *Mar. Pollut. Bull.* 96, 418–423.
- Schaffelke, B., Hewitt, C.L., 2007. Impacts of introduced seaweeds. *Bot. Mar.* 50 (5-6), 397–417.
- Sciberras, M., Schembri, P.J., 2007. A critical review of records of alien marine species from the Maltese Islands and surrounding waters (Central Mediterranean). *Mediterr. Mar. Sci.* 8 (1), 41–66.
- Sghaier, Y.R., Zakhama-Sraieb, R., Mouelhi, S., Vazquez, M., Valle, C., Ramos-Esplá, A., Astier, J., Verlaque, M., Charfi-Cheikhrouha, F., 2015. Review of alien marine macrophytes in Tunisia. *Mediterr. Mar. Sci.* 17 (1), 109–123.
- Smith, C.M., Walters, L.J., 1999. Fragmentation as a strategy for *Caulerpa* species: fates of fragments and implications for management of an invasive weed. *Mar. Ecol.* 20 (3-4), 307–319.
- Stachowicz, J.J., Bruno, J.F., Duffy, J.E., 2007. Understanding the effects of marine biodiversity on communities and ecosystems. *Annu. Rev. Ecol. Evol. Syst.* 38, 739–766.
- Stevens, D.T., 1999. Malta. In: United Nations Environment Programme (Ed.), Proceedings of the Workshop on Invasive *Caulerpa* Species in the Mediterranean, 125. MAP Technical Report Series, pp. 279–281.
- Streftaris, N., Zenetos, A., 2006. Alien marine species in the Mediterranean-the 100 'Worst Invasives' and their impact. *Mediterr. Mar. Sci.* 7 (1), 87–118.
- Streftaris, N., Zenetos, A., Papanathassiou, E., 2005. Globalisation in marine ecosystems: the story of non-indigenous marine species across European seas. *Oceanogr. Mar. Biol.* 43, 419–453.
- Tamburello, L., Maggi, E., Benedetti-Cecchi, L., Bellistri, G., Rattray, A.J., Ravaglioli, C., Rindi, L., Roberts, J., Bulleri, F., 2015. Variation in the impact of non-native seaweeds along gradients of habitat degradation: a meta-analysis and an experimental test. *Oikos* 124, 1121–1131.
- Tsiamis, K., Panayotidis, P., Zenetos, A., 2008. Alien marine macrophytes in Greece: a review. *Bot. Mar.* 51, 237–246.
- Tsiamis, K., Montesanto, B., Panayotidis, P., Katsaros, C., Verlaque, M., 2010. Updated records and range expansion of alien marine macrophytes in Greece (2009). *Mediterr. Mar. Sci.* 11, 61–79.
- Vazquez-Luis, M., Sanchez-Jerez, P., Bayle-Sempere, J.T., 2008. Changes in amphipod (Crustacea) assemblages associated with shallow-water algal habitats invaded by *Caulerpa racemosa* var. *cylindracea* in the western Mediterranean Sea. *Mar. Environ. Res.* 65, 416–426.
- Verlaque, M., Boudouresque, C.F., Meinesz, A., Gravez, V., 2000. The *Caulerpa racemosa* complex (caulerpales, ulvophyceae) in the Mediterranean Sea. *Bot. Mar.* 43, 49–68.
- Verlaque, M., Durand, C., Huisman, J.M., Boudouresque, C.F., Parco, Y., 2003. On the identity and origin of the Mediterranean invasive *Caulerpa racemosa* (Caulerpales, Chlorophyta). *Eur. J. Phycol.* 38, 325–339.
- Wallentinus, I., Nyberg, C.D., 2007. Introduced marine organisms as habitat modifiers. *Mar. Pollut. Bull.* 55, 323–332.
- Zenetos, A., Gofas, S., Morri, C., Rosso, A., Violanti, D., Garcia Raso, J., Cinar, M., Almogi-Labin, A., Ates, A., Azzurro, E., Ballesteros, E., Bianchi, C., Bilecenoglu, M., Gambi, M., Giangrande, A., Gravili, C., Hyams-Kaplan, O., Karachle, P., Katsanevakis, S., Lipej, L., Mastrototaro, F., Mineur, F., Pancucci-Papadopoulou, M., Ramos Espla, A., Salas, C., San Martin, 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. Introduction trends and pathways. *Mediterr. Mar. Sci.* 13 (2), 328–352. North America.
- Žuljević, A., Antolić, B., Onofri, V., 2003. First record of *Caulerpa racemosa* (caulerpales: chlorophyta) in the Adriatic Sea. *J. Mar. Biol. Assoc. UK* 83, 711–712.