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# 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)

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**Keywords**
*Caulerpa racemosa* var. *cylindracea*; coralligenous biocoenosis; invasion; Ionian Sea; sponges.

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## Abstract

The present work investigated the modifications induced by the spread of the green macroalga *Caulerpa racemosa* var. *cylindracea* (Bryopsidales, Chlorophyta) on the sponge assemblage of Apulian coralligenous concretions (Ionian Sea – Torre Ovo, Italy). The study of qualitative and quantitative sponge composition was carried out before (2004) and after (2006) the spread of this invasive alga by means of traditional (quadrat scraping) and photographic sampling methods. Results indicate that the spread of the green alga is concomitant with a significant decrease in percentage sponge cover both on horizontal- and on vertical-oriented substrates. In addition, strong modifications to the structure of the community in terms of repartition of the available substrate have been observed since the algal spread. Conversely, no major changes have affected the specific composition of the sponge assemblage, suggesting that at this stage of colonization the algal spread has not produced a loss of sponge biodiversity. However, there is a clear need to monitor closely the *C. racemosa* invasion to verify its long-term impact on the sponge assemblage.

## Problem

It has been estimated that about 900 species had been introduced into the Mediterranean Sea as a consequence of human activities (opening of the Suez Canal, ballast waters and international shipping, aquaculture, aquaria) (Streftaris *et al.* 2005; Zenetos *et al.* 2005, 2008). In some cases, these non-indigenous species have shown the ability to invade new environments and radically alter the structure and the functioning of native ecosystems, causing marked changes or threatening native biological diversity (Verlaque & Fritayre 1994; Davis *et al.* 1997; Occhipinti-Ambrogi 2000; Piazzi & Cinelli 2000; Shiganova *et al.* 2001; Mastrototaro & Brunetti 2006; Thessalou-Legaki *et al.* 2006; Longo *et al.* 2007). The spread of alien species in marine ecosystems is therefore an important cause of biological modifications as well as being generally difficult to control and evaluate (Piazzi *et al.* 2001a).

Intentional or accidental introductions of algal species in the Mediterranean Sea have been widely reported (Chambers *et al.* 1993; Verlaque 1994; Ribera & Boudouresque 1995; Richardson *et al.* 2000). In particular, members of the tropical and subtropical species of Bryopsidales exhibit traits typical of invasive species. *Caulerpa racemosa* (Forsskål) C. Agardh var. *cylindracea* (Sonder) Verlaque, Huisman et Boudouresque (*C. racemosa* hereafter), currently spreading in the Mediterranean Sea, represents one of the most important examples of invasive events of recent years (Verlaque *et al.* 2003, 2004; Piazzi *et al.* 2005). The South-western Australian invasive variety (Verlaque *et al.* 2003) can inhabit a wide range of subtidal hard and soft substrates (sand, mud, rocks, dead mattes of seagrasses) from 0 to 70 m depth (Argyrou *et al.* 1999; Capiomont *et al.* 2005). *Caulerpa racemosa* shows rapid growth (Piazzi *et al.* 1997) and can spread by fragmentation (Smith & Walters 1999) and sexual reproduction (Panayotidis & Žuljević 2001). Moreover, its spherical branchlets can act as propagules (Renoncourt & Meinesz 2002). The spreading of this alga seems to be a result of its asexual reproduction together with human activities (transport of propagules in ballast water, transport by anchors and fishing gear) (Piazzi *et al.* 1997; Renoncourt & Meinesz 2002), and could be favoured by other factors, such as alterations of current regimes and climatic changes, as hypothesized for other thermophilous species (Astraldi *et al.* 1995). It is likely that the recent increase in water temperature in the Mediterranean has accelerated the spread of this alga (Argyrou *et al.* 1999). Moreover, the increase in terrestrial sediments derived from human activities such as fire, deforestation, coastal construction, changes in river flow and dredging (Bourcier 1986; Airoldi *et al.* 1996) could damage Mediterranean native assemblages and further increase the competitiveness of *C. racemosa*, which is more tolerant to variations in sedimentation rate (Piazzi *et al.* 2005). *Caulerpa racemosa* is also a strong competitor and may easily reduce native algae (Piazzi *et al.* 2001b, 2005). A recent paper suggests possible allelopathic activity of a *Caulerpa* metabolite, caulerpenyne, which may play a role in the successful competition of the green alga with macrophytes (Raniello *et al.* 2007). Finally, *C. racemosa* is not limited by grazing of native herbivorous species (Ruitton *et al.* 2006).

In general, the interactions between *C. racemosa* and the indigenous Mediterranean communities have hardly been investigated, and mainly in reference to the impact of the alga on benthic native macrophytes (Giaccone & Di Martino 1995; Ceccherelli *et al.* 2000, 2002; Piazzi *et al.* 2001b, 2005, 2007; Occhipinti-Ambrogi & Savini 2003; Mastrototaro *et al.* 2004; Piazzi & Ceccherelli 2006). Few studies have detected the effect of *C. racemosa* spreading on animal assemblages from soft bottoms (Argyrou *et al.* 1999; Sandulli *et al.* 2004). Currently, there are no works on the effects produced by the presence of this green alga on the hard-bottom macrozoobenthos and, in particular, on the peculiar biocoenosis of great naturalistic importance such as coralligenous assemblages (Ballesteros 2006).

The aim of the present work is to investigate the effect of the spread of *C. racemosa* and the modifications induced by its colonization of the sponge assemblage of the Apulian coralligenous concretions (Ionian Sea – Torre Ovo, Italy). In this regard, a qualitative and quantitative analysis of the sponge community was carried out before (2004) and after (2006) the spread of *C. racemosa* in the study site using traditional (quadrat scraping) and photographic sampling methods.

## Material and Methods

The study site is located along the Apulian coast, at Torre Ovo, a small coastal town, 30 km from Taranto (SE Italy, Ionian Sea, 40°17′36″ N and 17°30′21″ E). In this site, a rich coralligenous assemblage is present from 10 to 18 m in depth. The typical biogenic formation mainly consists of the overlap of encrusting calcareous red algae. Some animal groups such as bryozoans, polychaetes and sponges contribute to construction of concretions. The area is affected by anthropic impacts caused by fishing, anchor damages and recreational diving activities. In recent years, changes of the sedimentation regime, due to the supply of terrestrial sediments derived from huge coastal construction, have also occurred. *Caulerpa racemosa* has been recorded at this site since 2003 (R. Baldacconi, personal observation).

At 15 m depth, 60 experimental units of 400 cm$^2$ were selected: 20 of them on horizontal substrates (inclination < 45°), 20 on vertical substrates (inclination > 45°) and 20 in small cavities (from 0.5 to 2 m height and from 0.3 to 1 m depth). In the months of August 2004 and August 2006, each experimental unit was photographed by SCUBA divers using a Casio Exilim digital camera with an underwater/waterproof case. The percentage cover of *C. racemosa* and of each species of sponge was evaluated in the laboratory (Balduzzi *et al.* 1985; Corriero *et al.* 2000). Pictures were analysed with a KURTA IS/ADB digitizer connected to a Macintosh PC to estimate the area of substrate covered by the green alga and discrete sponge species. The diversity index (H′) and evenness (J) were calculated on the basis of the percentage covers estimated by the photographic image analyses. Univariate statistical analysis (mean value, standard error with n = 20) was carried out on the percentage cover of *C. racemosa* and sponges. Differences in the percentage cover of the green alga and sponges between August 2004 and August 2006 were evaluated by applying the parametric Student's t-test, after dataset normalization. The relationship between the percentage cover of *C. racemosa* and all sponge species was estimated using Spearman's correlation coefficient ($r_s$).

In addition to the photographic survey, sponge samples were collected in August 2004 and 2006 by scraping off a surface of 400 cm$^2$ (20 × 20 cm) at 15 m depth (three randomly selected replicates for each substrate inclination). Specimens were fixed with 4% formaldehyde in sea water and preserved in 70% alcohol. Once in the laboratory, the sponges were first separated on the basis of their growth-form (erect, massive, encrusting, boring, creeping). Slides of dissociated spicules were prepared for each specimen to study the spicular arrangement and then to identify sponges at species level. Univariate statistical analysis (mean value, standard error with n = 3 replicates) was carried out on the number of species found.

## Results

### *Caulerpa racemosa* var. *cylindracea*

In August 2004, *Caulerpa racemosa* was present at the study site exclusively on horizontal substrates (six of 20

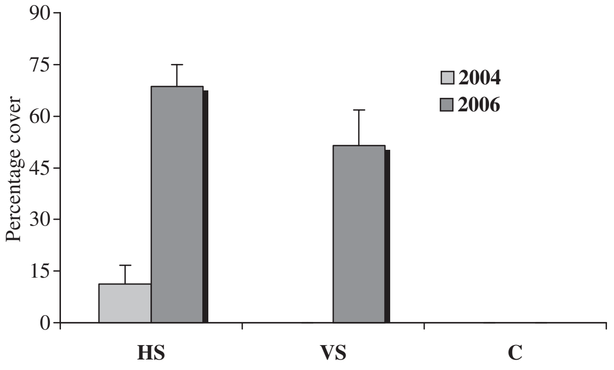

**Fig. 1.** *Caulerpa racemosa* var. *cylindracea*: percentage cover (mean ± SE, n = 20) on horizontal substrates (HS), on vertical substrates (VS) and in cavities (C).

experimental units) with low percentage cover values (11.3 ± 5.4%) (Fig. 1). The green algae formed small patches mixed with the native algal assemblages. Among them, a few species of the genus *Peyssonnelia* were the most common prostrate forms, and *Dasycladus vermicularis*, *Flabellia petiolata* and *Padina pavonica* were the most common erect ones. *Halimeda tuna*, *Codium bursa* and *Dictyota dichotoma* were present but less common. After 2 years (August 2006), *C. racemosa* formed a continuous dense green carpet, with a network of overlapping stolons, which also trapped sediment. In particular, the green algae showed a significant increase, spreading both on horizontal ($t = 10.2$, $P < 0.01$) and vertical substrates ($t = 5.4$, $P < 0.01$) with high percentage cover values (68.6 ± 6.3% and 51.5 ± 9.2%, respectively) (Fig. 1). *Caulerpa racemosa* was never found settled in small cavities (Fig. 1).

### Sponge assemblage

Samples from both 2004 and 2006 gave a total of 58 taxa of sponges, 51 of which were identified at species level (Table 1). Thirty-six of these species were also detected from analysis of the photographic survey (Table 1). In total, 51 species (87.9% of the species recorded) were found in 2004 and 54 (93.1%) in 2006. Forty-seven species (81%) were common to both sampling periods. Four species (6.9%) were exclusively detected in 2004 and seven (12%) in 2006. The sponge assemblage mainly consists of species typically found in coastal Mediterranean waters, previously reported for the nearby coralligenous concretions of Porto Cesareo (Corriero *et al.* 2004). One species, *Forcepia* (*Leptolabis*) *apuliae* (Sarà, 1969), can be considered a new record for the Ionian Sea.

The number of species showed a slight decrease between 2004 and 2006 both on horizontal and vertical substrates (from 18 to 11 and from 32 to 26, respectively) (Fig. 2A) (mean values ± SE: from 13 ± 2 to 8 ± 2 and from 30 ± 1 to 21 ± 3, respectively). The covering of substrates by sponge showed more marked changes, with a significant decrease both on horizontal and vertical substrates (from 30.6 ± 1.5% to 12.2 ± 4.1% on horizontal substrates, $t = 3.1$, $P < 0.01$; from 29.4 ± 3.1% to 17.6 ± 1.8% on vertical substrates, $t = 2.3$, $P < 0.05$) (Fig. 2B). As for the number of species, the percentage sponge cover was also almost unchanged between the two periods in the small cavities (from 30.0 ± 3.2% to 30.6 ± 0.9%) (Fig. 2B).

Spearman's correlation coefficient showed a negative correlation between the percentage cover of *C. racemosa* and both the number of sponge species detected from the analysis of photographic images ($r_s = -0.590$, $P < 0.01$) and the percentage sponge cover ($r_s = -0.443$, $P < 0.01$).

Both the diversity index (H′) and evenness (J) confirmed the trends observed for the number of species and the percentage sponge cover (Fig. 2C, D).

Differences between the two sampling periods were also observed by studying the distribution of the sponge growth-forms (erect, massive, encrusting, boring, creeping) at the study site.

On horizontal and vertical substrates the number of massive and encrusting species showed a slight decrease (on horizontal substrates, from 7 to 4 and from 4 to 2, respectively; on vertical substrates, from 13 to 10 and from 8 to 5, respectively) (Fig. 3A, B). In the cavities the distribution of the sponge growth-forms was almost unchanged (Fig. 3C).

In 2004, the most abundant species on horizontal substrates were *Cliona viridis* (present as $\beta$ encrusting form) (11.1 ± 2.3%), *Scalarispongia scalaris* (8.4 ± 1.8%) and *Crambe crambe* (4.3 ± 0.9%) (Fig. 4A). In 2006, *C. viridis* (6.2 ± 1.3%) and *S. scalaris* (3.2 ± 0.7%) showed a decrease in coverage values of about 50% (Fig. 4B).

On vertical substrates, *Crambe crambe* (9.5 ± 1.5%), *Oscarella lobularis* (3.7 ± 0.6%) and *Ircinia variabilis* (3.3 ± 0.7%) were the dominant species in 2004 (Fig. 4C). Two years later, *C. crambe* (9.1 ± 1.8%) was the only abundant species (Fig. 4D).

In the small cavities no differences between the dominant species (*Spirastrella cunctatrix*, *Agelas oroides* and *Phorbas tenacior*) were observed between 2004 and 2006 (Fig. 4E,F).

### *Caulerpa racemosa versus* sponge community

Photographic images from the study site highlight the ability of *C. racemosa* to overgrow several demosponges. The green alga covered encrusting, massive and erect species such as *Cliona viridis* (present in $\beta$ encrusting form)

**Table 1.** Sponges: list of 58 taxa found and their temporal and spatial distribution on horizontal substrates (HS), vertical substrates (VS) and cavities (C).

| | 2004HS | 2006HS | 2004VS | 2006VS | 2004C | 2006C |
|---|---|---|---|---|---|---|
| *Clathrina coriacea* (Montagu, 1818)[a] | | | + | | + | + |
| *Sycon* sp. | | | + | + | + | + |
| *Oscarella lobularis* (Schmidt, 1862)[a] | | | + | + | + | |
| *Plakortis simplex* Schulze, 1880 | | | + | + | + | + |
| *Jaspis johnstoni* (Schmidt, 1862) | + | + | + | + | + | + |
| *Penares helleri* (Schmidt, 1864) | | | | | + | + |
| *Erylus discophorus* (Schmidt, 1862) | | | | | + | + |
| *Erylus euastrum* (Schmidt, 1868) | | | | | + | |
| *Geodia conchilega* Schmidt, 1862 | | | | | | + |
| *Stoeba plicata* (Schmidt, 1868) | + | + | + | + | + | + |
| *Cliona celata* Grant, 1826[a] | + | + | + | + | | |
| *Cliona rhodensis* Rützler & Bromley, 1981[a] | + | + | + | | | |
| *Cliona schmidti* (Ridley, 1881)[a] | | | + | + | + | + |
| *Cliona viridis* Schmidt, 1862[a] | + | + | + | + | + | |
| *Pione vastifica* (Hancock, 1849) | | | | | | + |
| *Thoosa mollis* Volz, 1939 | + | | | | + | + |
| *Placospongia decorticans* (Hanitsch, 1895) | | | | | | + |
| *Spirastrella cunctatrix* Schmidt, 1868[a] | | | + | | + | + |
| *Prosuberites longispinus* Topsent, 1893[a] | | | | | + | + |
| *Suberites carnosus* (Johnston, 1842) | | | | | + | + |
| *Terpios fugax* Duchassaing & Michelotti, 1864[a] | | | + | | + | + |
| *Tethya aurantium* (Pallas, 1766)[a] | + | | | | | + |
| *Timea fasciata* Topsent, 1934 | | | | | + | + |
| *Timea stellata* (Bowerbank, 1866) | | | | | + | + |
| *Spiroxya heteroclita* Topsent, 1896 | | | | | | + |
| *Chondrosia reniformis* Nardo, 1847[a] | + | | + | + | + | |
| *Chondrilla nucula* Schmidt, 1862[a] | + | | + | + | | |
| *Acarnus tortilis* Topsent, 1892 | + | | | | | |
| *Forcepia* (*Leptolabis*) *apuliae* (Sarà, 1969) | | | | + | | |
| *Crambe crambe* (Schmidt, 1862)[a] | + | + | + | + | + | + |
| *Phorbas fictitius* (Bowerbank, 1866)[a] | + | | + | + | + | + |
| *Phorbas paupertas* sensu Boury-Esnault, 1971 | + | + | + | + | | |
| *Phorbas tenacior* (Topsent, 1925)[a] | + | | + | + | + | + |
| *Mycale* (*Mycale*) *lingua* (Bowerbank, 1866) | | | | | + | + |
| *Axinella damicornis* (Esper, 1794)[a] | | | + | + | + | + |
| *Axinella verrucosa* (Esper, 1794)[a] | | | + | + | + | + |
| *Bubaris vermiculata* (Bowerbank, 1866) | | | | | | + |
| *Achantella acuta* Schmidt, 1862[a] | | | + | | + | + |
| *Dyctionella incisa* (Schmidt, 1880) | | | + | + | | |
| *Topsentia aurantiaca* (Schmidt, 1862)[a] | | | | | + | + |
| *Agelas oroides* (Schmidt, 1864)[a] | | | + | + | + | + |
| *Haliclona* (*Halichoclona*) *fulva* (Topsent, 1893)[a] | | | + | + | + | + |
| *Haliclona* sp. | | | + | + | | |
| *Petrosia* (*Petrosia*) *ficiformis* (Poiret, 1789)[a] | + | + | + | + | + | + |
| *Ircinia variabilis* (Schmidt, 1862)[a] | + | + | + | + | + | + |
| *Sarcotragus foetidus* Schmidt, 1862[a] | + | + | | | | |
| *Scalarispongia scalaris* (Schmidt, 1862)[a] | + | + | + | + | | |
| *Fasciospongia cavernosa* (Schmidt, 1862)[a] | | | | | + | + |
| *Spongia* (*Spongia*) *officinalis* Linnaues, 1759[a] | | | | | + | + |
| *Spongia* (*Spongia*) *virgultosa* Schmidt, 1868[a] | | | | | + | + |
| *Dysidea avara* (Schmidt, 1862)[a] | | | + | + | + | + |
| *Pleraplysilla spinifera* (Schulze, 1879)[a] | | | | | + | + |
| *Aplysilla rosea* (Barrois, 1876)[a] | | | + | | + | |
| Demospongiae no. 1[a] | | | | | + | + |
| Demospongiae no. 2[a] | | | | | + | + |

**Table 1.** (*Continued*)

| | 2004HS | 2006HS | 2004VS | 2006VS | 2004C | 2006C |
|---|---|---|---|---|---|---|
| Demospongiae no. 3[a] | | | | + | | + |
| Demospongiae no. 4[a] | | | + | | | + |
| Demospongiae no. 5[a] | | | + | | | |
| Total number of taxa | 18 | 11 | 32 | 26 | 39 | 42 |

[a]Taxa also detected from the analysis of photographic images.

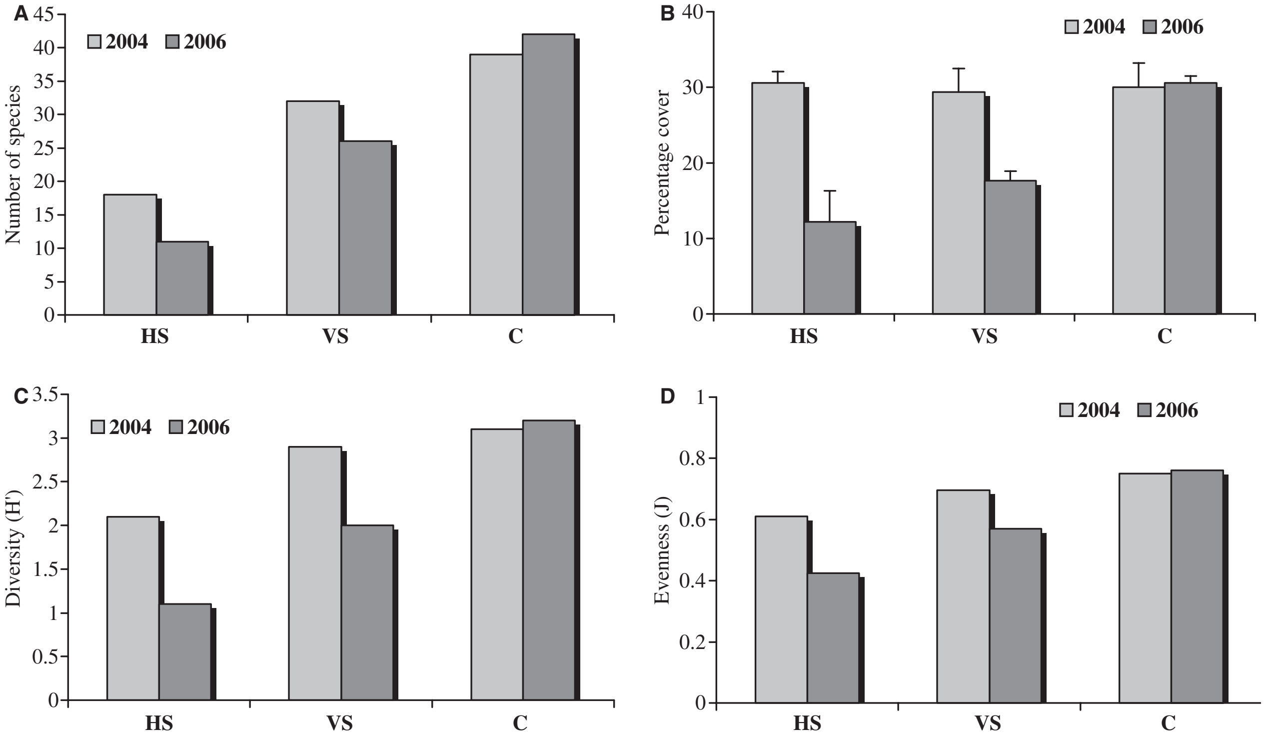

**Fig. 2.** Sponges: number of species (A), percentage sponge cover (mean ± SE, n = 20) (B), index of diversity (C) and evenness (D) on horizontal substrates (HS), vertical substrates (VS) and cavities (C).

(Fig. 5A), *Ircinia variabilis*, *Sarcotragus foetidus*, *Scalarispongia scalaris* (Fig. 5B), *Dysidea avara*, *Axinella damicornis* (Fig. 5C) and *Axinella verrucosa*. *Crambe crambe* was the only sponge not overgrown by the algae (Fig. 5D).

## Discussion

The evaluations of the effects produced by the spread of the green alga *Caulerpa racemosa* on both the Mediterranean animal and plant assemblages are not in complete agreement.

Most of the studies emphasize the loss of biodiversity of native assemblages in the presence of the algal spread. Large changes in the composition and abundance of macrofaunal assemblages of soft bottoms, attributable to the proliferation of the invasive alga, are reported for the coastal waters of the island of Cyprus (Argyrou *et al.* 1999). Whereas the dominant taxon before the appearance of *C. racemosa* was Gastropoda, after the algal expansion the dominant taxon was Polychaeta (Argyrou *et al.* 1999). Piazzi *et al.* (2007) observed that native macroalgal assemblages from rocky bottoms were affected by a significant decrease in encrusting and erect species, both articulated and foliose, whereas filamentous algae increased their abundance. Deep changes in the native algal assemblages are also reported for the seas of Taranto, where *C. racemosa* has almost taken the place of the endemic Mediterranean co-generic *Caulerpa prolifera* (Mastrototaro *et al.* 2004).

According to Piazzi & Ceccherelli (2006), such biological modifications are persistent, and the process of

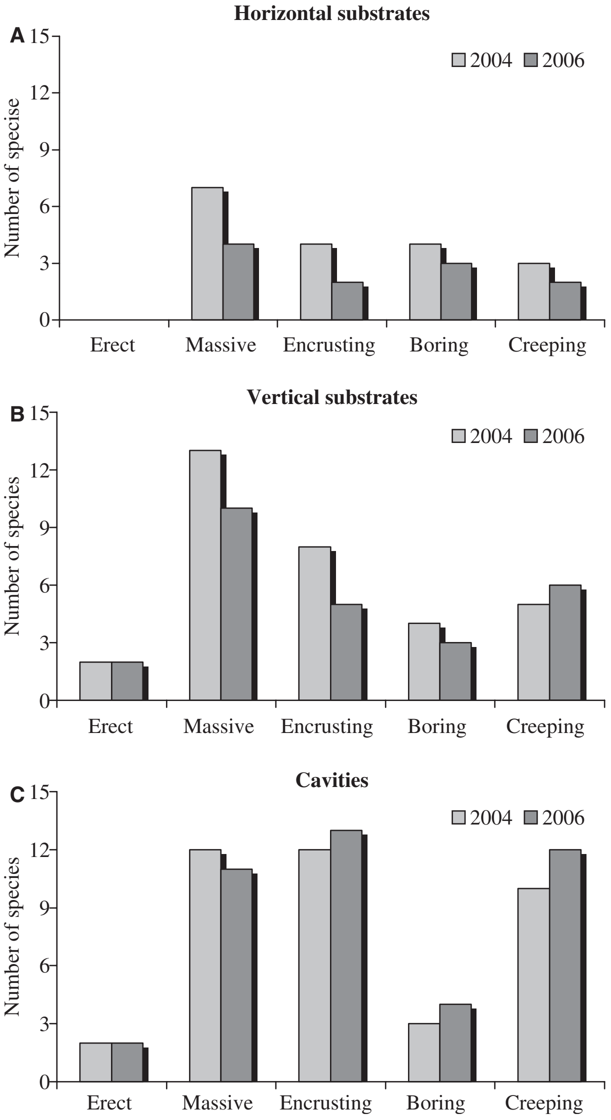

**Fig. 3.** Sponges: distribution of sponge growth-forms (erect, massive, encrusting, boring, creeping) among sampling periods, on horizontal substrates (HS), on vertical substrates (VS) and in cavities (C).

recovery of the native assemblages after the removal of the invasive alga appears to be quite slow.

Notwithstanding evidence of the strong environmental modifications due to the alga occurrence, not all authors agree with the negative opinion of this invasion process. A study of polluted soft bottoms showed the highest biodiversity values in the presence of *C. racemosa* meadows (Giaccone & Di Martino 1995). Therefore, the authors emphasize the positive function of the green alga on polluted sites where the native biocoenosis is highly degraded. A more complex scenario has been suggested by Sandulli *et al.* (2004), who highlight that the spread of *C. racemosa* in the Gulf of Taranto seems to have enhanced the abundance of meiofauna biomass, even if it seems to have caused a decrease in the diversity of some meiobenthic crustaceans.

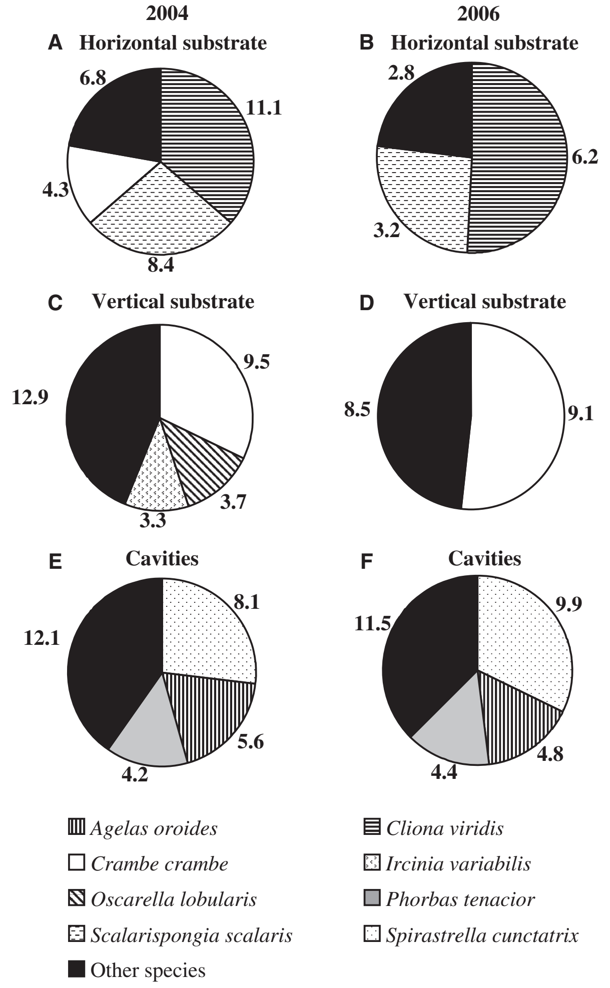

**Fig. 4.** Sponges: distribution of dominant species (percent cover > 3%) on horizontal substrates (A,B), on vertical substrates (C,D) and in cavities (E,F).

The relationships between sponges and introduced algal species have hardly been investigated, apart from one paper documenting the rapid invasion of a sponge-dominated deep-reef by *Caulerpa scalpelliformis* (Davis *et al.* 1997). The authors emphasize the substantial decline in the cover of sessile invertebrates, predominantly sponges, colonial ascidians and bryozoans, concomitantly with the algal spread.

Our study provides new information about the effects produced by this invasive alga on the animal assemblages inhabiting rocky substrates. The introduction of *C. racemosa* is a recent event in the studied area. During the 2 years of this study the spread of the alga was concomitant with a slight decrease in the number of

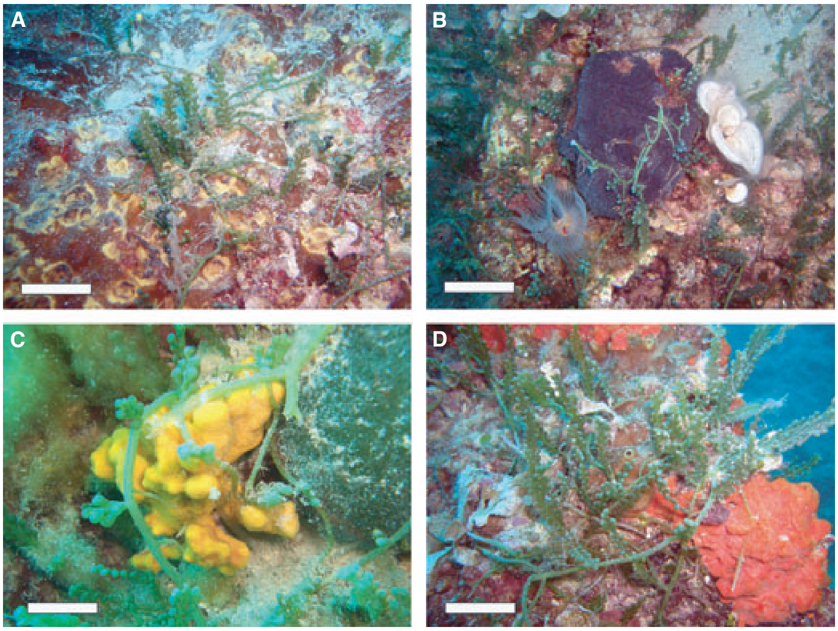

**Fig. 5.** *Caulerpa racemosa* var. *cylindracea*: the green alga partially covers some sponges. (A) *Cliona viridis* (present in *β* encrusting form) (bar = 4 cm). (B) *Scalarispongia scalaris* (bar = 5 cm). (C) *Axinella damicornis* (bar = 1 cm). In (D), *C. racemosa* is not able to extend its stolons on the sponge *Crambe crambe* (bar = 4 cm) (photos: R. Baldacconi).

sponge species and with a significant decrease in the sponge percentage cover. Where the alga was absent (small cavities), the percentage cover of sponges was almost unchanged (Fig. 2B).

At the study site, *C. racemosa* is able to overgrow many benthic organisms through a network of ramified stolons. With regard to sponges, *C. racemosa* grows on most of the conspicuous species detected using photographic image analysis. The green alga extends its stolons on the sponge specimens, anchored through numerous rhizoidal pillars that penetrate the sponge tissue to a depth of several millimeters (R. Baldacconi & G. Corriero, personal observation). Although some species of demosponges can live covered by a layer of other benthic organisms (Rützler 1970; Mercurio *et al.* 2006), the sediment trapped by the algal stolons of *C. racemosa* may affect sponge pumping activity, producing a shift to a less diverse, more silt-tolerant assemblage (Carballo *et al.* 1996).

It seems that *Crambe crambe*, an encrusting common species, is the only sponge which the alga does not overgrow. In fact, the percentage cover of *C. crambe*, estimated before and after the spread of *C. racemosa*, is almost comparable. According to Berlinck *et al.* (1992) and Uriz *et al.* (1996), this encrusting sponge produces a toxin with an anti-fouling effect, which could also inhibit the growth of this invasive alga.

The obtained results underscore the need to monitor the spread of *C. racemosa* with great attention to verify its long-term impact on the sponge community. Till now, the effect of the algal spread on sponge diversity has been moderate. However, a further diffusion of the alga, producing a continuous felt of stolons, could cause the occlusion of coralligenous cavities, leading to a dramatic decline in the diversity of sponges that often colonize such peculiar cryptic habitats.

## Summary

The modification of the sponge assemblage from Apulian coralligenous concretions induced by the spread of the green macroalga *Caulerpa racemosa* was studied by means of traditional (quadrat scraping) and photographic sampling. The study of qualitative and quantitative sponge composition was carried out before (2004) and after (2006) the spread of this invasive alga at the study site. The sponge assemblage showed a significant decrease in percentage cover, concomitant with the alga colonization both on horizontal and vertical substrates. Photographic images highlight the ability of *C. racemosa* to overgrow several demosponge species. It covered encrusting, massive and erect species, such as *Cliona viridis* (present in *β* encrusting form), *Scalarispongia scalaris*, *Axinella damicornis*. It seems that *Crambe crambe* was the only sponge not overgrown by the alga. According to the literature, this encrusting sponge produces a toxin with an anti-fouling effect, which could inhibit the growth of the invasive alga. Conversely, no major changes have affected the species composition of the sponge community, which consists of 58 species very common in coastal Mediterranean waters. This result suggests that, at this stage of colonization, the algal spread has not produced a loss of species richness. However, there is a clear need to monitor the *C. racemosa*

invasion with great attention to verify its impact on sponge assemblages on a long-term basis.

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## References

Airoldi L., Fabiano M., Cinelli F. (1996) Sediment deposition and movement over a turf assemblage in a shallow rocky coastal area of the Ligurian Sea. *Marine Ecology Progress Series*, **133**, 241–251.

Argyrou M., Demetropoulos A., Hadjichristophorou M. (1999) Expansion of the macroalga *Caulerpa racemosa* and changes in softbottom macrofaunal assemblages in Moni Bay, Cyprus. *Oceanologica Acta*, **22**, 517–528.

Astraldi M., Bianchi C.N., Gasparini G.P., Morri C. (1995) Climatic fluctuations, current variability and marine species distribution: a case study in the Ligurian Sea (North-west Mediterranean). *Oceanologica Acta*, **18**(2), 139–149.

Balduzzi A., Pansini M., Pronzato R. (1985) Estimation par relévements photographiques de la distribution de spongiaires et bryozoaires dans une grotte sous-marine du Golfe de Naples. *Rapport Commission International Mer Méditerranée*, **29**(5), 131–134.

Ballesteros E. (2006) Mediterranean coralligenous assemblages: a synthesis of present knowledge. *Oceanography and Marine Biology: An Annual Review*, **44**, 123–195.

Berlinck R.G.S., Braekman J.C., Daloze D. (1992) Crambines C1 e C2: two further ichthyotoxic guanidine alkaloids from the sponge *Crambe crambe*. *Journal of Natural Products*, **55**, 528–532.

Bourcier M. (1986) Evolution en cinq années des herbiers à *Posidonia oceanica* et du macrobenthos circalittoral, action conjungée des activités humaines et des modifications climatiques. *Vie et Milieu*, **36**, 1–8.

Capiomont A., Breugnot E., den Haan M., Meinesz A. (2005) Phenology of a deep-water population of *Caulerpa racemosa* var. *cylinfracea* in the Northwestern Mediterranean Sea. *Botanica Marina*, **48**, 80–83.

Carballo J.L., Naranjo S.A., Garcia-Gomez J.C. (1996) Use of marine sponges as stress indicators in marine ecosystems at Algeciras Bay (Southern Iberian Peninsula). *Marine Ecology Progress Series*, **135**, 109–122.

Ceccherelli G., Piazzi L., Cinelli F. (2000) Response of non-indigenous *Caulerpa racemosa* (Forsskål) J. Agardh to the native seagrass *Posidonia oceanica* (L.) Delile: effect of density of shoots and orientation of edges of meadows. *Journal of Experimental Marine Biology and Ecology*, **243**, 227–240.

Ceccherelli G., Piazzi l., Balata D. (2002) Spread of introduced *Caulerpa* species in macroalgal habitats. *Journal of Experimental Marine Biology and Ecology*, **280**, 1–11.

Chambers P.A., Barko J.M., Smith C.S. (1993) Evaluation of invasions and declines of submerged aquatic macrophytes. *Journal of Aquatic Plant Management*, **31**, 218–220.

Corriero G., Scalera Liaci L., Ruggiero D., Pansini M. (2000) The sponge community of a semi-submerged Mediterranean cave. *PSZN: Marine Ecology*, **21**(1), 85–96.

Corriero G., Gherardi M., Giangrande A., Longo C., Mercurio M., Musco L., Nonnis Marzano C. (2004) Inventory distribution of hard bottom fauna from the marine protected area of Porto Cesareo (Ionian Sea): Porifera and Polychaeta. *Italian Journal of Zoology*, **71**, 237–245.

Davis A.R., Roberts D.E., Cummins S.P. (1997) Rapid invasion of a sponge-dominated deep-reef by *Caulerpa scalpelliformis* (Chlorophyta) in Botany Bay, New South Wales. *Australian Journal of Ecology*, **22**, 146–150.

Giaccone G., Di Martino V. (1995) Le Caulerpe in Mediterraneo: un ritorno del vecchio bacino Tetide verso il dominio Indo-Pacifico. *Biologia Marina Mediterranea*, **2**(2), 607–612.

Longo C., Mastrototaro F., Corriero G. (2007) Occurrence of *Paraleucilla magna* (Porifera: Calcarea) in the Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom*, **87**, 1749–1755.

Mastrototaro F., Brunetti R. (2006) The non-indigenous ascidian *Distaplia bermudensis* in the Mediterranean: comparison with the native species *Distaplia magnilarva* and *Distaplia lucillae* sp. nov. *Journal of the Marine Biological Association of the United Kingdom*, **86**, 181–185.

Mastrototaro F., Petrocelli A., Cecere F., Matarrese A. (2004) Non indigenous species settle down in the Taranto seas. *Biogeographia*, **25**, 47–53.

Mercurio M., Corriero G., Gaino E. (2006) Sessile and non-sessile morphs of *Geodia cydonium* (Jameson) (Porifera, Demospongiae) in two semi-enclosed Mediterranean bays. *Marine Biology*, **148**(3), 489–501.

Occhipinti-Ambrogi A. (2000) Biotic invasions in a Mediterranean lagoon. *Biological Invasions*, **2**(2), 165–176.

Occhipinti-Ambrogi A., Savini D. (2003) Biological invasion as a component of global change in stressed marine ecosystems. *Marine Pollution Bulletin*, **46**, 542–551.

Panayotidis P., Žuljević A. (2001) Sexual reproduction of the invasive green algae *Caulerpa racemosa* var. *occidentalis* in the Mediterranean Sea. *Oceanologica Acta*, **24**, 199–203.

Piazzi L., Ceccherelli G. (2006) Persistence of biological invasion effects: recovery of macroalgal assemblages after removal of *Caulerpa racemosa* var. *cylindracea*. *Estuarine, Coastal and Shelf Science*, **68**, 455–461.

Piazzi L., Cinelli F. (2000) Effects of the spread of the introduced Rhodophyceae *Acrothamnion preissii* and *Womersleyella setacea* on the macroalgal community of *Posidonia oceanica* rhizomes in the Western Mediterranean sea. *Cryptogamie Algologie*, **21**(3), 291–300.

Piazzi L., Balestri E., Magri M., Cinelli F. (1997) Expansion de l'algue tropicale *Caulerpa racemosa* (Forsskål) J. Agardh (Bryopsidophyceae, Chlorophyta) le long de la coûte toscane (Italie). *Cryptogamie Algologie*, **18**, 343–350.

Piazzi L., Balata D., Ceccherelli G., Cinelli F. (2001a) Comparative study of the growth of the two co-occurring introduced green algae *Caulerpa taxifolia* and *Caulerpa racemosa* along the Tuscan coast (Italy, Western Mediterranean). *Cryptogamie Algologie*, **22**, 459–466.

Piazzi L., Ceccherelli G., Cinelli F. (2001b) Threat to macroalgal diversity: effects of the introduced green alga *Caulerpa racemosa* in the Mediterranean. *Marine Ecology Progress Series*, **210**, 149–159.

Piazzi L., Balata D., Ceccherelli G., Cinelli F. (2005) Interactive effect of sedimentation and *Caulerpa racemosa* var. *cylindracea* invasion on macroalgal assemblages in the Mediterranean Sea. *Estuarine, Coastal and Shelf Science*, **64**, 467–474.

Piazzi L., Balata D., Foresi L., Cristaudo C., Cinelli F. (2007) Sediment as a constituent of Mediterranean benthic communities dominated by *Caulerpa racemosa* var. *cylindracea*. *Scientia Marina*, **71**(1), 129–135.

Raniello R., Mollo E., Lorenti M., Gavagnin M., Buia M.C. (2007) Phytotoxic activity of caulerpenyne from the Mediterranean invasive variety of *Caulerpa racemosa*: a potential allelochemical. *Biological 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.

Ribera M.A., Boudouresque C.F. (1995) Introduced marine plants, with special reference to macroalgae: mechanism and impact. *Progress in Phycological Research*, **11**, 187–268.

Richardson D.M., Pyšek P., Rejmánek M., Barbour M.G., Panetta F.D., West C.J. (2000) Naturalization and invasion of alien plants: concepts and definitions. *Diversity & Distributions*, **2**(15), 93–107.

Ruitton S., Verlaque M., Aubin G., Boudouresque C.F. (2006) Grazing on *Caulerpa racemosa* var. *cylindracea* (Caulerpales, Chlorophyta) in the Mediterranean Sea by herbivorous fishes and sea urchins. *Vie et Milieu*, **56**(1), 33–41.

Rützler K. (1970) Spatial competition among Porifera: solution by epizoism. *Oecologia*, **5**, 85–95.

Sandulli R., Carriglio D., Deastis S., Marzano A., Gallo D'Addabbo M., Gerardi D., De Zio Grimaldi S. (2004) Meiobenthic biodiversity in areas of the Gulf of Taranto (Italy) exposed to high environmental impact. *Chemistry and Ecology*, **20**, 376–386.

Sarà M. (1969) Specie nuove di demosponge provenienti dal coralligeno pugliese. *Bollettino dei Musei e degli Istituti Biologici dell'Università di Genova*, **37**, 89–96.

Shiganova T.A., Mirzoyan Z.A., Studenikina E.A., Volovik S.P., Siokou-Frangou I., Zervoudaki S., Christou E.D., Skirta A.Y., Dumont H.J. (2001) Population development of the invader ctenophore *Mnemiopsis leidyi* in the Black Sea and other seas of the Mediterranean basin. *Marine Biology*, **139**, 431–445.

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. *PSZN: Marine Ecology*, **20**, 307–319.

Streftaris N., Zenetos A., Papathanassiou E. (2005) Globalisation in marine ecosystems – the story of non indigenous marine species across European Seas. *Oceanography and Marine Biology: An Annual Review*, **43**, 419–453.

Thessalou-Legaki M., Zenetos A., Kambouroglou V., Corsini Foka M., Kouraklis P., Dounas C., Nicolaidou A. (2006) The establishment of the invasive crab *Percnon gibbesi* (H. Milne Edwards, 1853) (Crustacea: Decapoda: Grapsidae) in Greek waters. *Aquatic Invasions*, **1**(3), 133–136.

Uriz M.J., Becerro M.A., Tur J.M., Turon X. (1996) Location of toxicity within the Mediterranean sponge *Crambe crambe* (Demospongiae: Poecilosclerida). *Marine Biology*, **124**(2), 583–590.

Verlaque M. (1994) Inventaire des plantes introduites en Méditerranée: origines et répercussions sur l'environnement et les activités humaines. *Oceanologica Acta*, **17**, 1–23.

Verlaque M., Fritayre P. (1994) Modifications des communautés algales méditerranéennes en présence de l'algue envahissante *Caulerpa taxifolia* (Vhal) C. Agardh. *Oceanologica Acta*, **17**, 659–672.

Verlaque M., Durand C., Huisman J.M., Boudouresque C.F., Le Parco Y. (2003) On the identity and origin of the Mediterranean invasive *Caulerpa racemosa* (Caulerpales, Chlorophyta). *European Journal of Phycology*, **38**, 325–329.

Verlaque M., Afonso-Carrillo J., Gil-Rodriguez M.C., Durand C., Boudouresque C.F., Le Parco Y. (2004) Blitzkrieg in a marine invasion: *Caulerpa racemosa* var. *cylindracea* (Bryopsidales, Chlorophyta) reaches the Canary Islands (NE Atlantic). *Biological Invasions*, **6**, 269–281.

Zenetos A., Cinar M.E., Pancucci-Papadopoulou M.A., Harmelin J.G., Furnari G., Andaloro F., Bellou N., Streftaris N., Zibrowius H. (2005) Annotated list of marine alien species in the Mediterranean with records of the worst invasive species. *Mediterranean Marine Science*, **6**(2), 63–118.

Zenetos A., Meriç E., Verlaque M., Galli P., Boudouresque C.-F., Giangrande A., Cinar M.E., Bilecenoğlu M. (2008) Additions to the annotated list of marine alien biota in the Mediterranean with special emphasis on Foraminifera and Parasites. *Mediterranean Marine Sciences*, **9**(1), 119–165.