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OLD AND NEW BIOINVASIONS IN THE CALABRIAN TYRRHENIAN COASTS

Introduction

In the Mediterranean basin the green algae by genus *Caulerpa* is represented by 7 taxa: *C. prolifera* (Forsskål) J.V. Lamouroux, *C. chemnitzia* (Esper) J.V. Lamouroux [as *Caulerpa racemosa* var. *occidentalis* (J.Agardh) Børgesen], *C. Mexicana* Sonder *ex* Kützing, *C. scalpelliformis* (R. Brown *ex* Turner) C. Agardh, *C. taxifolia* (M. Vahl) C. Agardh, *C. cylindracea* Sonder and *C. racemosa* var. *lamourouxii* f. *requienii* (Montagne) Weber van Bosse (Cormaci *et al*. 2014; Guiry and Guiry 2014; Verlaque *et al*. 2000; Verlaque *et al*. 2003). Only the species *C. prolifera* is considered indigenous while the others are regarded as alien species (Zenetos *et al*. 2010). Amongst these, there is an old acquaintance, actually named *C. cylindracea* Sonder and a new one, known as *C. taxifolia* (Vahl) C. Agardh var. *disticophylla* (Sonder) Verlaque, Huisman and Procaccini. *C. cylindracea*, indopacific and termophilic species of wide spread, was formerly reported in the Tunisian coasts (Hamel 1926) and actually is spreading in the Western Mediterranean basin (Piazzi *et al*. 1994). This invasive species, formerly known as *Caulerpa racemosa*, was recently identified as *Caulerpa racemosa* var. *cylindracea* (Sonder) Verlaque *et* Boudouresque through a morphological and genetic study (Verlaque *et al*. 2003). Finally, bio-molecular investigations (Belton *et al*. 2014) stated the genetic independence of *Caulerpa racemosa* var. *cylindracea*, as a species-level entity and it was established the reinstatement

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of the original scientific name as *Caulerpa cylindracea* Sonder. The last invader *Caulerpa taxifolia* (Vahl) C. Agardh var. *distichophylla* (Sonder) Verlaque, Huisman and Procaccini was reported, for the first time, in the Eastern Mediterranean Sea in 2007 for the southern coast of Turkey (Cevik *et al*. 2007) and later in the western basin, for the northeastern shoreline of Sicily (Cormaci and Furnari 2009; Meinesz *et al*. 2010; Jongma *et al*. 2013; Musco *et al*. 2014), but also for the islands of Cyprus (Aplijioti *et al*. 2016; Çicek *et al*. 2013; Tsiamis *et al*. 2014), Malta (Schembri *et al*. 2015) and Rhodes (Aplikioti *et al*. 2016).

The study was carried out, from 1999 to 2009, in the south-western Mediterranean Sea, along the Calabrian Tyrrhenian coasts from Praia a Mare (Cosenza) to Scilla (Reggio Calabria) for a coastline of 242 km in length. Twenty-two sampling sites were chosen in the infralittoral zone on rocky and soft bottoms from 1 to 10 m depth (Fig. 1). The assessment of human pressure, caused by shipping and fishing activities was established consulting statistical data released by the harbour authority of Vibo Valentia Port (38°43’26’’ N, 16°07’40’’ E) that provided numerical data on maritime traffic related to the yearly means for the time series 1999-2009.

Results and discussion

Caulerpa cylindracea Sonder

The spreading of *Caulerpa cylindracea* in the Calabrian Tyrrhenian coasts has vastly increased since its first report dated 1999 (Cantasano 2001). Really, just ten years after its first observation, the species has scattered, all along, the regional coast for a total length of 62.8 km, as a single report for 12.7 km of coastline (Fig. 1). The samples were collected only in shallow habitats easily detectable, even though it can thrive until 40 m depth (Piazzi *et al*. 1997). In all the 22 sites, the species was collected in surface waters and mostly from 4 to 6 meters depth (Fig. 2).

In the study areas, the species has invaded rocky/sandy bottoms and especially the borders of *Posidonia oceanica* (L.) Delile meadows (Table 1, Fig. 3).

So, *C. cylindracea* has spread all along the Calabrian Tyrrhenian coasts in exposed and sheltered sites, in shaded and sunny locations, in pristine and in polluted areas, and, generally, under different environmental conditions. Finally, from the data resulting from the survey, it is highlighted that most of the collecting sites are subjected to high pressures for shipping and tourist activities, but the first ones are, certainly, prevailing (Fig. 4).

The carrying trade through the harbour of Vibo Valentia, mostly coming from Italian countries (94%), showed an annual trend of 166 ships and most

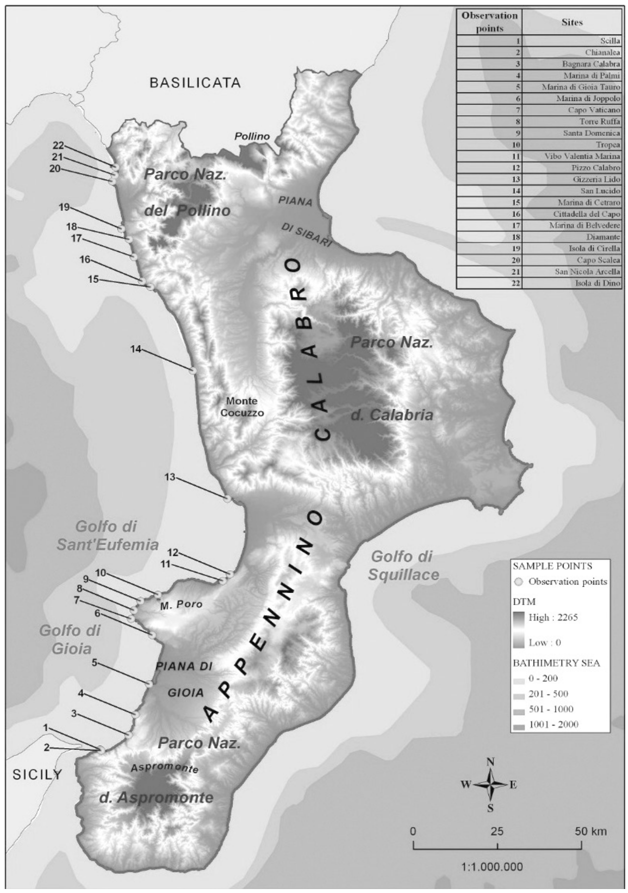

Fig. 1. – Distribution of *C. cylindracea* in the Calabrian Tyrrhenian coasts (from Cantasano *et al*. 2017).

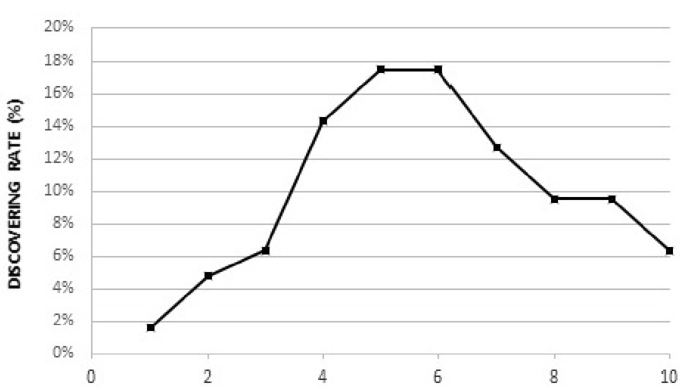

Fig. 2. – *C. cylindracea* discovering rates at the different depths of collecting sites (from Cantasano *et al*. 2017).

Table. 1. – *Calabrian sites invaded by C. cylindracea from 1999 to 2009 years. * First Calabrian report (Cantasano 2001). Substrate: PO = Posidonia oceanica meadow with low density; DM = dead "matte" of Posidonia oceanica; CS = Coarse sand; FS = Fine sand; RS = Rocky substratum.*

SITES – GEOGRAPHICAL COORDINATES	DEPTH	SUBSTRATE	DATE COLLECTIONS
1. Scilla – 38°15′25.43″N-15°42′51.71″E	**3-4 m**	**PO**	**01/09/2000**
2. Chianalea – 38°15′15.73″N-15°43′04.96″E	**5-6 m**	**CS**	**10/09/2000**
3. Bagnara Calabra – 38°17′45.00″N-15°48′41.73″E	**4-5 m**	**CS**	**15/09/2009**
4. Marina di Palmi – 38°21′08.06″N-15°50′07.35″E	**6-7 m**	**PO**	**05/09/2001**
5. Marina di Gioia Tauro – 38°26′11.56″N-15°53′00.57″E	**8-10 m**	**CS**	**05/09/2007**
6. Marina di Joppolo – 38°34′22.67″N-15°53′44.73″E	**5-6 m**	**RS**	**10/09/2008**
7. Capo Vaticano – 38°37′04.49″N-15°49′29.03″E	**9-10 m**	**PO**	**15/09/2001**
8. * Torre Ruffa - 38°38′31.65″N - 15°50′04.93″E	**1-2 m**	**RS**	**30/09/1999**
9. Santa Domenica – 38°40′02.53″N-15°51′23.73″E	**6-10 m**	**PO**	**05/09/2002**
10. Tropea – 38°41′04.53″N-15°55′01.16″E	**4-5 m**	**RS**	**10/09/2002**
11. Vibo Valentia Marina – 38°43′14.36″N-16°08′21.06″E	**5-6 m**	**FS**	**03/09/2006**
12. Pizzo Calabro – 38°44′20.78″N-16°09′50.27″E	**2-8 m**	**RS**	**10/09/2006**
13. Gizzeria Lido – 38°56′52.71″N-16°09′30.38″E	**4-6 m**	**FS**	**01/10/2005**
14. San Lucido – 39°18′15.14″N-16°02′44.60″E	**6-7 m**	**RS**	**15/09/2005**
15. Marina di Cetraro – 39°32′14.18″N-15°54′08.33″E	**4-5 m**	**RS**	**10/09/2004**
16. Cittadella del Capo – 39°33′12.88″N-15°52′25.50″E	**5-6 m**	**RS**	**01/09/2004**
17. Marina di Belvedere – 39°37′15.05″N-15°50′43.73″E	**7-9 m**	**PO**	**03/09/2003**
18. Diamante - 39°40′11.71″N-15°49′45.36″E	**4-5 m**	**PO**	**30/10/2009**
19. Isola di Cirella – 39°41′57.38″N-15°48′13.06″E	**2-10 m**	**DM**	**01/10/2003**
20. Capo Scalea – 39°49′50.37″N-15°46′24.07″E	**7-9 m**	**PO**	**09/10/2003**
21. San Nicola Arcella – 39°50′53.97″N-15°46′57.55″E	**3-4 m**	**PO**	**20/09/2004**
22. Isola di Dino – 39°52′13.18″N-15°47′09.66″E	**6-7 m**	**PO**	**30/09/2004**

of commercial arrivals was recorded in summer months, as the 30% of the whole traffic. Three macro areas, as are Western Mediterranean Sea, Eastern Mediterranean Sea and Atlantic Ocean, are involved in this trade exchange but most of the commercial traffic (88%) came from the Italian region of Sicily. From the data released by the harbor authority of Vibo Valentia, there are three main harbor areas that, proceeding from north to south, are located close to Cetraro, Vibo Valentia and Gioia Tauro towns. These coastal regions are affected by the widespread presence of *C. cylindracea*, as shown in the following figure where it is highlighted the high statistical relationship between the presence of the species and the great commercial importance of these three harbors characterized by a leading sea trade and by a large shipping activity (Fig. 5).

In conclusions, the species spreads in the Calabrian Tyrrhenian coast under a large array of environmental conditions and it is, often, found

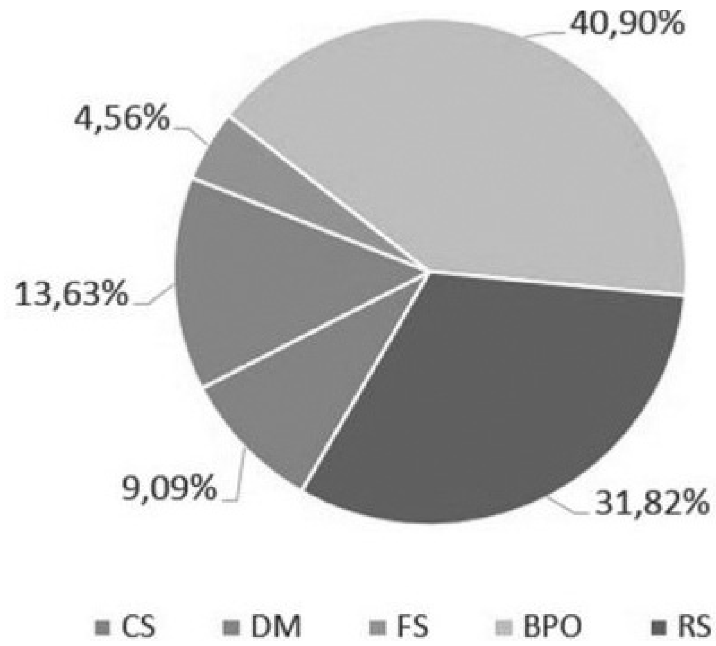

Fig. 3. – Relative cover rates of substrata allocations in the spreading of *C. cylindracea* in collecting sites. CS = Coarse Sand; BPO = Borders of Posidonia oceanica meadows; DM = Dead “Matte” of *Posidonia oceanica*; FS = Fine Sand; RS = Rocky Substrata (from Cantasano *et al*. 2017).

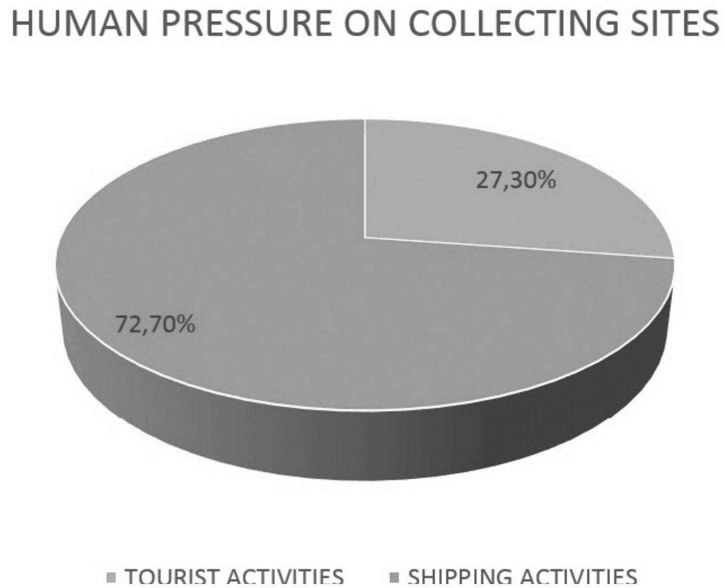

Fig. 4. – Patterns of human pressure on collecting sites (from Cantasano *et al*. 2017).

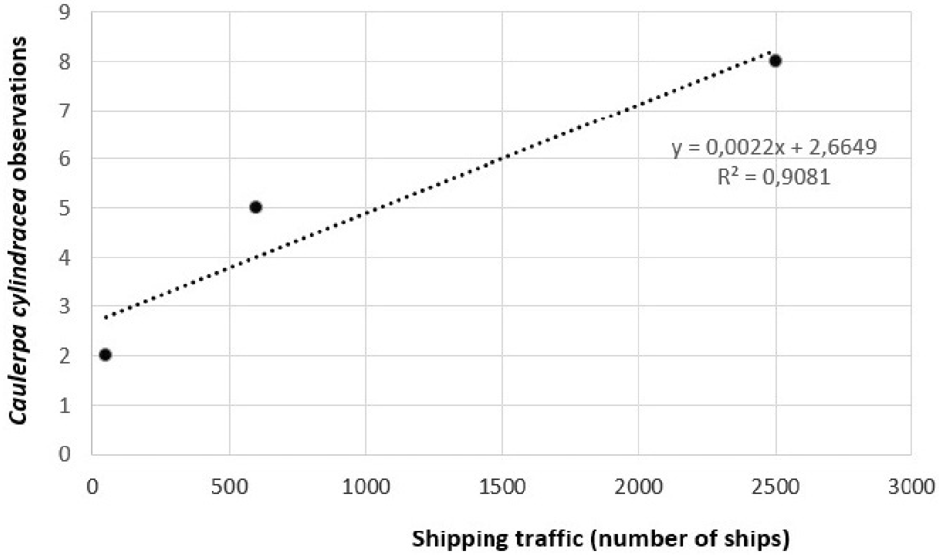

Fig. 5. – Relationship between the shipping activities in harbor districts and the presence of *C. cylindracea* (from Cantasano *et al.* 2017).

close to regional harbours for a dispersal mechanism, via boating traffic, as highlighted by literature (Airoldi and Cinelli 1997; Piazzi *et al.* 2007), confirming the great tolerance of the species to high levels of pollution and sedimentation. Really, the spreading of *C. cylindracea* is supported by the commercial traffic coming from the southern part of the Western basin. By this way, the key-role of some Mediterranean harbours, such as Vibo Valentia (Calabria, Southern Italy), could explain the fast spreading of alien species along the Calabrian coasts. The results of this survey confirm the widespread distribution of *C. cylindracea* on the Calabrian Tyrrhenian coasts, in areas closed to harbours and subjected to high rate of sedimentation.

Caulerpa taxifolia var. *disticophylla* (Sonder) Verlaque, Huisman and Procaccini

In this paper it has been reported, also, the presence of this invasive strain which is expanding into the Western Mediterranean Sea. By this way, we report new populations of *C. taxifolia* var. *distichophylla* in four places of Sicily (Brucoli Bay, Augusta Harbour, Terrauzza Bay, Vendicari natural reserve in the Ionian Sea) and, for the first time, in a southern station of the Calabrian Tyrrhenian coast (Fig. 6).

In general, where present, *C. taxifolia* var. *distichophylla* was more abundant and had longer fronds (ca 14÷16 cm) in sheltered areas, on dead

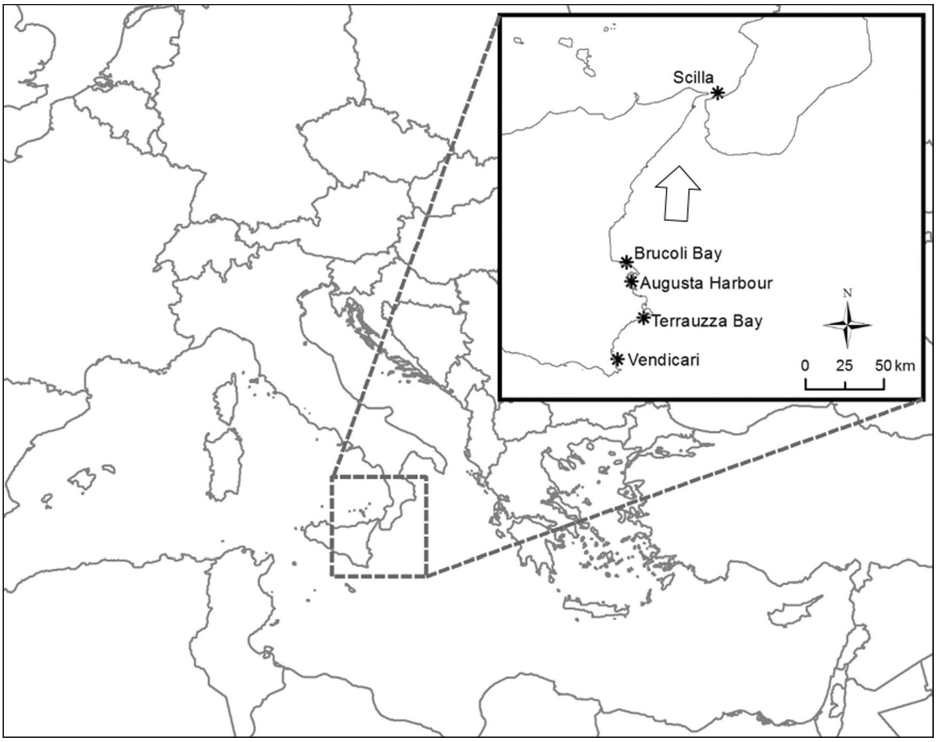

Fig. 6. – Map showing the new sampling sites of *Caulerpa taxifolia* var. *distichophylla* in the Western Mediterranean Sea.

"*matte*" of *Posidonia oceanica* beds and at the periphery of the meadows, where the alga was less dense. On rocky seabed covered with fine debris the most common algal species present along with *C. taxifolia* var. *distichophylla* were *Padina pavonica* (Linnaeus) Thivy, *Dasycladus vermicularis* (Scopoli) Krasser, *Flabellia petiolata* (Turra) Nizamuddin, *Dictyota dichotoma* (Hudson) J. V. Lamouroux, *Stypocaulon scoparium* (Linnaeus) Kützing and *Lophocladia lallemandii* (Montagne) F. Schmitz. In sandy and/or muddy bottoms *C. taxifolia* var. *distichophylla* is almost always the only species present. In all sites surveyed, *C. taxifolia* var. *distichophylla* was always found in reophilic environments like stretches of coastline protected by rocky reefs and/or seagrass meadows. Furthermore, *C. taxifolia* var. *distichophylla* appeared to prefer reduced light conditions but the species was also present in places where light was abundant. In these last conditions, the alga had short (< 6÷7 cm) fronds while in shady places the thallis exceeded 16÷18 cm in height. It is difficult to establish with certainty the factors that are driving the spread of *C. taxifolia* var. *distichophylla* in the Mediterranean Sea. However, we agree with the contention of other authors that this species arrived in the Mediterranean Sea via aquarium trade and shipping activities. Our observations indicate that this species is following the same migration route as for most Lessepsian species. In conclusion, the mechanisms of spreading of *C. taxifolia* var. *distichophylla* is the same as those of *C. cylindracea*, that formerly invaded the Western Mediterranean basin.

Conclusions

To date, there are more of three hundred alien species, from faunal to floristic ones, entered into the Mediterranean Sea. This process was originally restricted to the eastern sector of the basin, characterized by a poor biodiversity degree with a low level of endemism restricted to the 5% of total biota. However, the process of tropicalization in the Mediterranean Sea is, actually, ongoing and it is increasing in the Western area of the basin. The effects of this trend are not predictable in the short and long period. Anyway, it is impossible to foresee if the diversification of Mediterranean biota could increase, on time, its marine biodiversity or, instead, produce a loss in the quantitative and qualitative patterns of Mediterranean ecosystems. This state of a great uncertainty and biological variability suggests, therefore, a management control directed towards risky situations and, anyway, it induces a monitoring program of coastal marine ecosystems and an up-to-date mapping of benthonic biocenosis so to warrant the protection of the Mediterranean endemic species. This goal could be realized only through a close coordination between technical, scientific and political sectors, altogether engaged in problem solving.

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