



Caulerpa cylindracea Sonder invasion modifies trophic niche in infralittoral rocky benthic community



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ABSTRACT

The Mediterranean basin is one of the most invaded seas of the world. Invasive species have affected coastal benthic communities inducing structural changes. Since first reports, in the early 90s, *Caulerpa cylindracea* is considered one of the most important invasive event in the Mediterranean Sea where it has invaded large areas of soft bottoms, seagrass meadows and rocky shores. To assess effects of *C. cylindracea* in rocky ecosystems, benthic food webs have been compared between invaded and non-invaded coastal conditions through stable isotopes analyses. In addition, the convex hull area of the two types of conditions has been calculated as a proxy for the total extent of trophic diversity within each food web. Results have shown that the trophic niche width is at least 1.4 times wider in invaded conditions than in non-invaded conditions. In addition, this study gives further evidence of similar feeding analogies between the invasive herbivore fish, *Siganus luridus* and native herbivore fish *Sparisoma cretense* as both are feeding at the same isotopic level. This investigation provides with new scientific data to assess bionvasions in invaded and non-invaded conditions at assemblage level in coastal systems.

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1. Introduction

The Mediterranean, a semi enclosed sea, is one of the most affected areas worldwide by invasive species, which represent up to 5% of described flora and fauna in the basin (Boudouresque et al., 2005; Occhipinti-Ambrogi and Sheppard, 2007; Galil, 2009; Zenetos et al., 2012).

Lessepsian migrations through the Suez Canal is the major driving force for this bioinvasion (Nunes et al., 2014) but other factors as globalization and international trade, climate change, anthropogenic activities including aquaculture, shipping and transportation are also responsible (Streftaris et al., 2005; Occhipinti-Ambrogi, 2007). These new inhabitants modify natural and local communities occupying ecological niches of native species through predation or competition. In addition they alter nutrient cycling, food resources, reproductive procedures of many native organisms, sedimentation, bioturbation and they reduce

light penetration, create new habitat and produce overgrazing and anoxia amongst others (Boudouresque et al., 2005; Piazzì and Balata, 2008; Katsanevakis et al., 2010, 2014; Bulleri et al., 2011). At least 81 species have been documented to affect biodiversity with negative or positive impacts of various extent and intensity, ranging from single-species interactions to effects on entire ecosystems processes and wider ecosystem function (Katsanevakis et al., 2014). Amongst these, macroalgae *Caulerpa cylindracea* Sonder, 1845, native from the southwestern coast of Australia, has broadly colonized soft bottoms, seagrass meadows and rocky shores ranging from 0 up to 70 m in the Mediterranean Sea (Klein and Verlaque, 2008). A consequence of the spreading of *C. cylindracea* is the alteration of beta diversity of the areas they colonize (Piazzì and Balata, 2008) by reducing the diversity and abundance of native macroalgae, especially turf and encrusting species (Piazzì et al., 2001). In addition, *C. cylindracea*, may entirely modify the community structure and trophic flows (Katsanevakis et al., 2014). Further on *C. cylindracea* is known as a chemical engineer as it forms compact multilayers mats of up to 15 cm thick that trap sediments, beneath which an anoxic layer may develop (Piazzì et al., 2007; Klein and Verlaque, 2008). In turn, this modifies the

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quality and intensity of physical, chemical and hydrodynamical factors as well as the number and quality of shelters which substantially modifies trophic webs (e.g. [Piazzi et al., 2007](#); [Cacabelos et al., 2012](#)). In particular, in *Posidonia oceanica* (Linnaeus) Delile, 1813 meadows, *C. cylindracea* seems to be able to increase organic matter and sulphide levels in sediments, as well as microbial activity, contributing to seagrass decline ([Holmer et al., 2009](#)). All these changes are likely to have an impact on the trophic structure of infaunal communities ([Casu et al., 2009](#); [Deudero et al., 2011](#)) and may have far-reaching negative consequences for ecosystem stability. In addition in infralittoral rocky areas, ecosystems have been deprived of the valuable function of algal forests due to alterations in the community structure and native food webs caused by invasive fish species ([Sala et al., 2011](#) in [Katsanevakis et al., 2014](#)).

Stable Isotopes Analysis (SIA) techniques can be used to study effects of invasive species in food webs in a rapidly and cost-effectively way ([Kovalenko and Dibble, 2011](#)). The total extent of trophic niche diversity can be described by estimating the total area occupied by species in the isotope niche space and by measuring the overall density of species packing in this niche ([Layman et al., 2007a](#)). The “niche” is the sum of interactions (especially trophic) that link species in an ecosystem ([Elton, 1927](#)). It is the specified trophic “role” of that species ([Leibold, 1995](#)). SIA techniques have become a common alternative to stomach content analysis to study niche width, providing for time-and-space-integrated representations of the trophic ecology of organisms ([Layman et al., 2007b](#)). Relative position of organisms in the $\delta^{15}\text{N}$ - $\delta^{13}\text{C}$ bi-plot space can reveal important aspects of trophic structure and existing quantitative metrics can be a powerful tool to test ecological theory and study ecological response to anthropogenic impacts ([Layman et al., 2007b](#)).

In general, the presence of a new basal resource such as *C. cylindracea* would be expected to create a greater degree of trophic diversity with higher carbon and nitrogen isotopic values having implications at community and ecosystem level ([Deudero et al., 2011](#)). However, the effects of non-native species on marine assemblages may vary at different spatial and temporal scales ([Ceccherelli and Campo, 2002](#); [Bulleri et al., 2010](#)) and also within different biotic and abiotic conditions ([Piazzi and Balata, 2009](#); [Bulleri et al., 2008](#)). Given the fact that in the Mediterranean Sea over the last decades climate and anthropogenic conditions have facilitated the invasion by approximately 1000 non-native species ([Galil, 2007](#); [Zenetos et al., 2012](#)) it is important to continue conducting investigations in this research field. Under the scenario of changes in trophic structure of communities invaded by *C. cylindracea*, we examined differences in coastal macrobenthic communities of invaded and non-invaded conditions in Lampedusa Island. For this purpose stable isotopes analysis techniques have been applied to:

- (1) Describe food webs in invaded and non-invaded conditions in coastal rocky bottoms
- (2) test the hypothesis that the introduction of a new source of primary production and basal resource can cause an enlargement of trophic niche within the food web

2. Material and methods

2.1. Experimental design and sampling methods

Sampling was performed in the northern coast of Lampedusa Island in November 2013, during the general peak of seaweed production of *C. cylindracea* ([Piazzi et al., 2001](#)). This coast is

characterized by steep rocky substrates, dominated by photophilous algae. Infralittoral phytobenthic communities in the investigated area of the island are characterized by the presence of the *Cystoseiretum strictae* Molinier 1958 and facies characterized by the dominance of *Halopteris scoparia* (Linnaeus) Sauvageau, 1904, *Halopteris filicina* (Grateloup) Kützing, 1843 and *Padina pavonica* (Linnaeus) Thivy, 1960 ([Alongi et al., 1993](#); [Scammacca et al., 1993](#)).

In this area, four surfaces of 1600 cm² (40 × 40 cm quadrat) were sampled at depths between 9.5 and 11.5 m: two invaded surfaces by *C. cylindracea* (hereinafter invaded conditions) and two surfaces colonized solely by native macroalgae (hereinafter non-invaded conditions) ([Fig. 1](#)). The frequency of *C. cylindracea* in each invaded surface, estimated *in situ* through a quadrat with a grid of lines ([Bianchi et al., 2004](#)), resulted higher than 0.9 (15 out of 16 quadrats were covered with *C. cylindracea*) while non-invaded surfaces were totally colonized by native macroalgae. The surfaces were sampled by scuba divers using a standard airlift sampling device and by scraping macrofauna species of the food web. For this study macroalgae (*C. cylindracea*, *Codium bursa* (Olivi) *C. Agardh*, 1817) and invertebrates species (Brachyura spp, Capitallidae spp, Gammaridea spp, Gastropoda spp, *Lysidice* spp, Nemerterea spp, Palaemon spp, Porifera spp, Serpulidae spp, Sipuncula spp, *Hermodice carunculata* (Pallas, 1766)) were sampled. Once in the laboratory, benthic fauna and flora were sorted using a binocular microscope and identified. Organisms were frozen at -20 °C until tissue preparation for SIA.

In addition, two native macrobenthivore fish species (*Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817) and *Spondyliosoma cantharus* (Linnaeus, 1758)) were chosen to investigate the presence of an indirect effect at higher trophic levels due to the presence of *C. cylindracea*. To investigate the direct trophic effect, three herbivore fishes – the native *Sparisoma cretense* (Linnaeus, 1758) and *Sarpa salpa* (Linnaeus, 1758)) and the Lessepsian species (*Siganus luridus* (Rüppell, 1829), with similar sizes were sampled by spear fishing in the same surfaces where benthic sampling was carried out. The native fishes considered are typical inhabitants of the rocky bottoms in the study area and most of them occur in high abundance ([Azzurro et al., 2013](#)) while *S. luridus* recently colonized the islands of the Straits of Sicily competing with native herbivore fishes for food ([Azzurro et al., 2007](#)). Due to their high mobility, three individuals per fish species were randomly caught over both invaded and non-invaded conditions. At laboratory a piece of muscle tissue from each specimen was dissected and frozen at -20 °C until preparation for SIA.

2.2. Stable isotopes analyses (SIA)

Macroalgae were rinsed in distilled water, and visible epiphytes were removed before drying the macroalgae for stable isotope analyses. In the case of invertebrates, when required, the exoskeletal parts, valves or shells were removed, and only the soft body tissues were considered for SIA in order to avoid acidification ([Ng et al., 2007](#)) and for fish, muscle tissue samples were analyzed. Biological samples of invertebrates and fish were rinsed with distilled water to remove residual salt and carbonates. All biological samples (macroalgae, invertebrates and fish) were then dried at 60 °C for 24 h and ground to a fine powder using a mortar and pestle. A minimum quantity of 2 ± 0.1 mg of dried sample is required for SIA. Therefore, when possible 2 ± 0.1 mg of dried and powdered sample was placed into a tin cup and combusted for ¹³C and ¹⁵N isotopic analysis with a continuous flow mass spectrometer (Thermo Finnegan Delta x-plus). In the case of fishes, macroalgae and large zoobenthic specimens there was sufficient amount of organic matter and each individual was treated as an independent sample in the SIA analyses. However, for very small invertebrates,

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