Coral Reefs
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NOTE

Pioneer settlement of the cold-water coral *Desmophyllum dianthus* (Esper, 1794) on plastic

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Abstract Larval settlement is a critical step for sessile benthic species such as corals, whose ability to thrive on diverse natural and anthropogenic substrates may lead to a competitive advantage in the colonization of new environments with respect to a narrow tolerance for a specific kind of substratum. Plastic debris, widespread in marine waters, provides a large, motile, and solid substratum supporting a highly diverse biological community. Here we present the first observation of a floating plastic bottle colonized by the deep-sea coral *Desmophyllum dianthus*. The density pattern and co-occurring species composition suggest a pioneer behavior of this coral species, whose peculiar morphologic plasticity response when interacting with the plastic substrate (i.e., low density polyethylene) has not been observed before. The tolerance of *D. dianthus* for such plastic substrate may affect ecological processes in deep water environments, disrupting interspecific substrate competition in the benthic community.

Keywords Plastic debris · Scleractinian coral · Mediterranean Sea · Encrustation pattern · Substrate competition

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Introduction

Factors such as habitat selection and larval recruitment may have profound implications for sessile benthic species such as corals, in which planktonic larvae constitute the dispersal stage of their life history (Burgess et al. 2012). The ability of corals to settle on diverse substrates, both natural and anthropogenic, confers a competitive advantage over species with a narrow tolerance for a specific kind of substratum (Dubé et al. 2016). For example, the coral species *Oculina patagonica* and *Caryophyllia inornata* are particularly successful in colonizing piers and metal wrecks, respectively, showing higher abundance than on natural substrata (Salomidi et al. 2013; Caroselli et al. 2015). *Tubastraea* corals can easily grow on concrete (Ho et al. 2017) and shipwrecks (Soares et al. 2020), and metal floating objects are a potential rafting substrate for corals (Hoeksema et al. 2012).

Plastic litter is pervasive in the marine environment and particularly macroplastic (> 1 cm) provides a large and solid substratum which can support a biological community (Crocetta et al. 2020; De-La-Torre et al. 2021). Recent

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findings show a just preference for plastic substrates by benthic invertebrate larvae, also supported by a faster larval settlement that on natural and other artificial substrates (Goldstein et al. 2014; Chase et al. 2016; Pinochet et al. 2020). A few reports show the successful colonization of plastic debris by anthozoan species, including alcyionacean (Carugati et al. 2021) and scleractinian corals (Hoeksema et al. 2018), mostly on abandoned, lost or derelict fishing gear (e.g., Rech et al., 2016; Hoeksema and Hermanto 2018; Valderrama Ballesteros et al. 2018; Battaglia et al. 2019).

The role of plastic as a vector for macro-fauna dispersal is overlooked, although it may promote the long-distance spread of invasive species (both corals and associated microorganisms) over biogeographic barriers (Hoeksema et al. 2018) and alter macrobenthic community structure and ecology (de Carvalho-Souza et al. 2018; Lamb et al. 2018). The United Nations Environment Program (2019) recently underlined the need for more research focusing on the interactions between plastic and coral species at a global scale. Observations of plastic accumulation and interactions with cold-water corals in the Mediterranean region are particularly encouraged to clarify the potential impact of marine litter in deep-sea ecosystems (Ramirez-Llodra et al. 2013). Here we describe some puzzling aspects about the first observation of a pioneer settlement of the solitary, deep- and cold-water coral *Desmophyllum dianthus* (Esper, 1794) on a floating plastic bottle retrieved during a field campaign on the Central Mediterranean Sea (Thyrrhenian Sea).

Materials and methods

Data have been collected during the AQUATILIS Expedition at Ponza Island (Tyrrhenian Sea, Italy) in April 2018. The sampling site was located 0.8 km South-East of Ponza harbor, close to a group of emerged rocks ("Formiche Bank", 40° 3′ 5.8″ N – 12° 58′ 41.0″ E, Fig. 1), and characterized by a complex hydrodynamism that promotes vortex formation with the accumulation of plastic debris in the area (Macali et al. 2018). During a night dive, a floating hard yellow plastic bottle with a small piece of rope attached and fouling biota was collected for visual inspection. The plastic bottle was measured and photographed from several orientations to describe the degree of biofouling. Three pieces of the bottle were cut with scissors, washed in ultrapure water and processed for polymeric characterization by Attenuated Total Reflection Fourier-Transform Infrared (ATR-FTIR) spectroscopy (see ESM Material and Methods). Specimens of the fouling biota were also collected for species identification and morphometric analysis (see ESM Material and Methods).

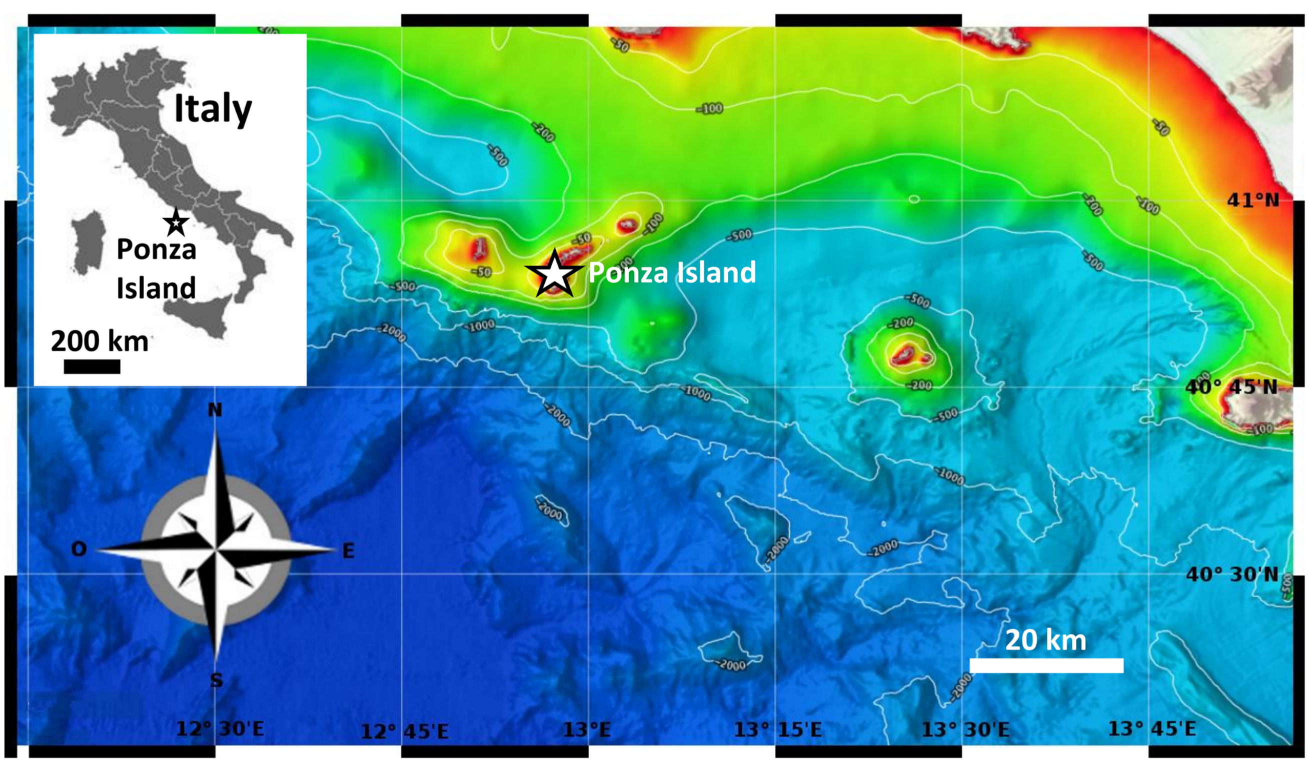

Fig. 1 Bathymetric map of the Central Tyrrhenian Sea and the study area (Ponza Island)

Results and discussion

The plastic bottle measured 44.13 × 25.88 × 7.85 cm (Fig. 1a) and was marked by the label "Razzo" on the top lid, likely referred to the Brazilian company of household hygiene and cleaning products (www.razzo.com.br), which can be assumed as a potential origin. The plastic, possibly used as a subsurface mooring buoy at sea, was found intact, with negligible signs of weathered surface. Based on the ATR-FTIR spectrum and a float test (see ESM results, ESM Fig. 1), the macroplastic was identified as a low density (LD) polyethylene (PE), one of the polymers mostly used in packaging industries (PlasticsEurope 2020) and the most common one found in marine waters worldwide (Cózar et al. 2014; Suaria et al. 2020).

Individuals (n = 6) of the solitary coral *D. dianthus* were found settled both on the hard plastic and on the rope attached (Fig. 2b, c). The only other two species attached

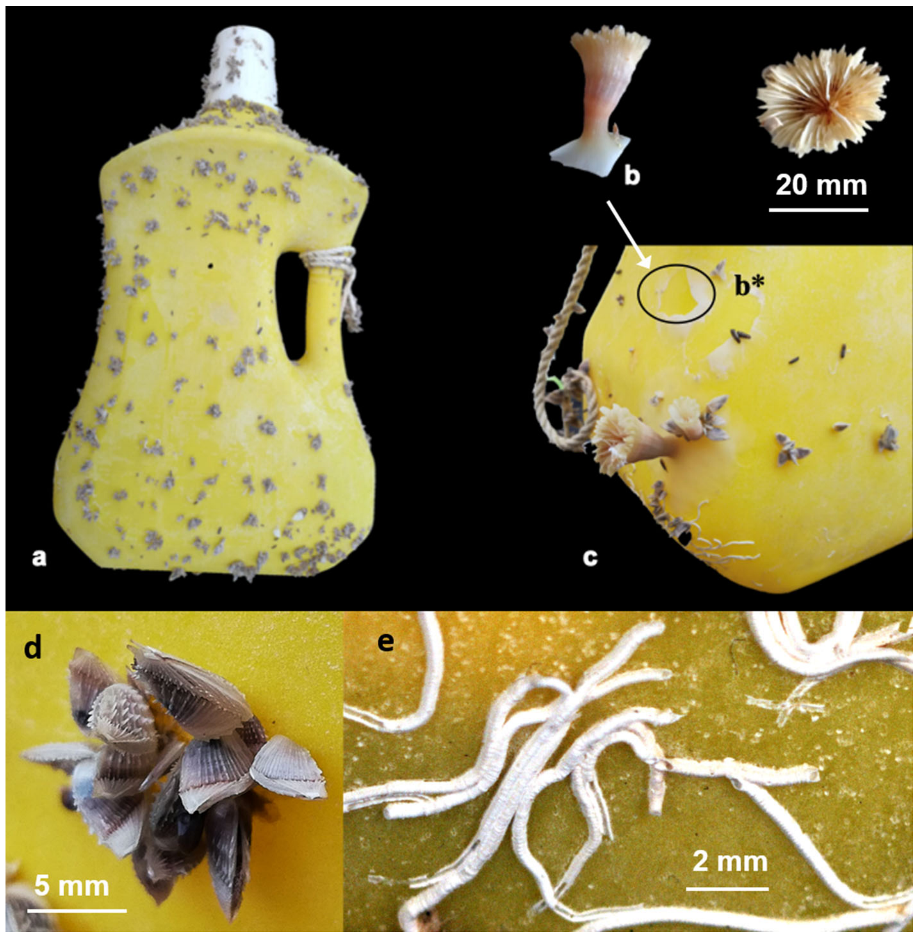

Fig. 2 **a** Hard plastic bottle collected at the Formiche Bank (Ponza Island, Central Tyrrhenian Sea); detail of **b** a specimen of *D. dianthus* settled on the plastic and **c** the extension of its basal plate (b*) on the plastic. **d** specimens of *Lepas pectinata* and **e** tubes of unidentified sessile polychaetes

Table 1 Corallum greater diameter and height of each collected specimens of *Desmophyllum dianthus* with corresponding estimated age classes based on the two extreme growth rate estimates available (0.5 mm yr^{-1} and 2 mm yr^{-1}; Risk et al. 2002; Adkins et al. 2004)

Sample	Greater diameter (mm)	Height (mm)	Minimum estimated age (yr)	Maximum estimated age[1] (yr)	Mean estimated age (yr)
P01	25.0	25	12.5	50.0	20.0
P02	1.5	1.5	0.8	3.0	1.2
P03	16.5	23.5	11.8	47.0	18.8
P04	13.5	23.5	11.8	47.0	18.8
P05	5.5	9.0	4.5	18.0	7.2
P06	8.0	12.5	6.3	25.0	10.0

The mean indicated was estimated using the mean value of the two growth rate estimates (1.25 mm yr^{-1})

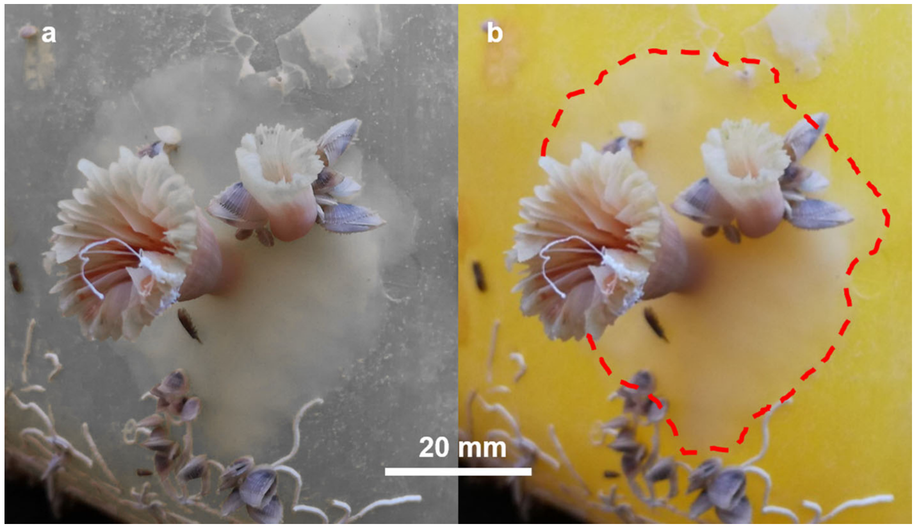

Fig. 3 Detail of the extension of *D. dianthus* basal plates on the macroplastic. The image was edited to emphasize the coral basal plates on the anthropogenic substratum. **a** yellow color desaturated; **b** original color with basal plate outlined in red

were the cirriped *Lepas pectinata* and tubes of unidentified sessile polychaetes (Fig. 2d, e). Barnacles of the genus *Lepas* are commonly found on floating plastic debris where they serve as foundation species (Gil & Pfaller 2016), thus they likely colonized the macroplastic when it was floating at the surface. On the contrary, *D. dianthus* most likely had colonized the macroplastic while it was submerged and attached to the seafloor with the rope. *Desmophyllum dianthus* is a cold-water scleractinian coral, occurring in the upper bathyal zone (200–2500 m) and frequently associated with frame-building species, like *D. pertusum* and *Madrepora oculata* (Roberts et al. 2009), contributing to the reef framework as aggregated colonies or ''clumps of specimens''. *Desmophyllum dianthus* is reported to occur in deep waters at hundreds to thousands of meters depth, with the shallowest reported depth being 7 m depth in subantarctic waters (Försterra et al. 2005) and 100 m in the Mediterranean Sea (Bo et al. 2017).

According to morphological measurements, the age of coral specimens was estimated based on available growth rates of *D. dianthus* (Table 1), a slow-growing coral (0.5–2.0 mm yr^{-1} in height) with a long lifespan up to 200 years (Risk et al. 2002; Adkins et al. 2004). The plastic bottle can be dated an average of 20 years (12.5–50.0) as the age of the oldest coral observed (i.e., P01 in Table 1). The presence of corals of very different size classes and corresponding ages (Table 1) indicates the multi-year residence of the plastic at sea, under environmental conditions which favored the settlement during multiple reproduction events. Given their depth distribution which does not reach surface waters, corals most likely settled on the plastic bottle while it was fixed on the seafloor. The detachment of the bottle can thus be dated about 1.2 year (0.8–3.0) as the age of the youngest coral observed (i.e., P02 in Table 1, because younger corals would be observed if the bottle was still on the bottom for further time).

The presence of coral specimens of different size and age on the plastic may be explained by further independent colonization, supporting the hypothesis of this LD PE bottle as suitable substrate for the species. Notably, all coral specimens showed an exceptional lateral extension of the basal plate (see for comparison Gori et al. 2016), which covered the surrounding area for several cm^{-2} around each corallum (Fig. 2b, c), covering most of the available smooth surface of the plastic bottle (Fig. 3). This characteristic has never been observed for this species on natural substrata, possibly representing a specific response to the plastic surface. A wider basal plate could be advantageous to prevent settlement of other organisms on the free available space, and indeed no other species characteristic of deep sea environments were found on the plastic bottle. This may indicate a pioneer settlement of *D. dianthus* when a free plastic substratum becomes available at depth, preventing the possibilities of colonization by other species. The population of *D. diantus* surrounding the location where the bottle was abandoned on the seafloor may have been dominant, contributing to successful repeated settlement on the plastic. A further explanation for the larger basal plate may be that a larger attachment area gives a better holdfast, which may be more critical on a smooth surface like plastic.

Our report from the Mediterranean Sea represents the first evidence of a floating plastic bottle colonized by the cold-water coral *D. dianthus,* displaying an atypical growth pattern never observed on natural substrates. The absence of other coral species as well as other encrusting fouling, despite the size of the plastic and its long residence time at sea, suggests a possible pioneer behavior of *D. dianthus*, which seems to compete for substrate through a rapid and wide extension of its basal plate. Considering that *D. dianthus* has been listed as Endangered in the latest IUCN report on the conservation status of Mediterranean Anthozoa (Bo et al. 2017), being threatened by habitat degradation due to anthropogenic activities, its tolerance to plastic substrates may ironically favor its dispersal. Nevertheless, this tolerance for plastic substrate deserves further investigation, both for its possible interactions with ecological processes in deep water environments and for its potential application in the field of reef-restoration, in this case targeted on deep-water environments.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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