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ORIGINAL ARTICLE

The coral assemblages of an off-shore deep Mediterranean rocky bank (NW Sicily, Italy)

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Abstract

In this study we characterized the deep assemblages dwelling at 200–250 m depth on a large shoal off Capo St. Vito Promontory (Northwestern coast of Sicily, South Tyrrhenian Sea) by means of ROV-imaging. Two assemblages of suspension feeders, dominated by the gorgonian *Callogorgia verticillata* and by the black coral *Leiopathes glaberrima*, together with a tanatocoenosis of the colonial yellow scleractinian coral *Dendrophyllia cornigera*, were examined. The three main species were significatively distributed into two areas corresponding to different habitat preferences: a more elevated hardground hosting black corals and a gently sloping, silted rocky bottom hosting the other coral species. The study area is subjected to a heavy pressure from the professional fishery, resulting in mechanical damage to numerous colonies, some of which are then overgrown by various epibionts including a parasitic bioluminescent zoanthid, new for the Mediterranean fauna and tentatively identified as *Isozoanthus primoidus*. In the Mediterranean Sea, these deep off-shore rocky banks are widely known among recreational and professional fishermen due to the rich fish fauna inhabiting these areas. However, there has been still little effort put into quantifying and characterizing the entity of the impact and its consequences on the benthic communities, which may represent, as in this case, only a partial picture of their original structure and extent.

Introduction

In the last decades, the coral communities of the Mediterranean Sea have been widely studied in the shallow-water depth range, resulting in numerous papers dealing with the species distribution and biology and ecology of the most common species (Gili & Ballesteros 1992; Harmelin & Marinopoulos 1994; Weinbauer & Velimirov 1995; Vafidis *et al.* 1997; Gili & Coma 1998; Ribes *et al.* 1999; Coma *et al.* 2000, 2006; Garrabou *et al.* 2002; Santangelo *et al.* 2004; Linares *et al.* 2005, 2008; Tsounis 2005; Tsounis *et al.* 2006; Rossi *et al.* 2008; Gori *et al.* 2011a,b). Great attention was given also to cold-water corals living below 300 m depth (Tursi *et al.* 2004; Taviani *et al.* 2005a,b; Zibrowius & Taviani 2005; Carlier *et al.* 2009; Freiwald & Taviani 2009; Freiwald *et al.* 2009; Orejas *et al.* 2009; D'Onghia *et al.* 2010; Mastrototaro *et al.* 2010; Vertino *et al.* 2010). However, recent ROV surveys revealed that antipatharians and gorgonians, living down to the limits of the continental shelf, may be locally very abundant, representing keystone species in the structuring of the Mediterranean deep circa-littoral rocky bottoms (Aguiliar 2006; Bo *et al.* 2009, 2011a,b,c, 2012; Cerrano *et al.* 2010). The role of these species within the benthic ecosystem has been highlighted by numerous studies conducted in Atlantic deep-waters. These works revealed that,

as cold water scleractinian corals, these species also promote habitat heterogeneity by providing new colonizable niches and increasing the complexity of the ecosystem (Krieger & Wing 2002; Buhl-Mortensen & Mortensen 2004, 2005; Mortensen & Buhl-Mortensen 2004; Metaxas & Davis 2005; Penn *et al.* 2005; Etnoyer & Warrenchuk 2007; Buhl-Mortensen *et al.* 2010; Cerrano *et al.* 2010). Suspension-feeder communities, indeed, play an important role in the pelagic-benthic transfer of energy and biomass, by recycling particulate organic matter sinking from the upper photosynthetic layers and transferring it to the other benthic components (Gili & Coma 1998). In particular, corals are of crucial importance in the functioning of the sublittoral temperate assemblages occurring on hard dim-lighted substrata and affected by strong currents (Zabala & Ballesteros 1989; Gili & Coma 1998; Coma *et al.* 2000; Coma & Ribes 2003).

The habitat selection for gorgonian and black corals in the deep circa-littoral zone of the Mediterranean Sea is constrained mainly by the hydrodynamic regime and the type and availability of substrate, with major differences among sites in the population structure of the species (Bo *et al.* 2009, 2011a,b,c, 2012). In particular, it is likely that off-shore rocky banks, due to their elevated topography and isolated position, are potentially subjected to local turbulences, resulting, especially at their tops, in the development of a rich suspension feeding community (Genin *et al.* 1986, 1992; Bo *et al.* 2011a).

Along the Italian continental shelf, the nautical charts report hundreds of such deep [illegible] banks. Despite the abundance of these structures and their potential coral richness, only a few ROV surveys have been conducted to characterize their fauna (Giaccone 1967; Di Geronimo *et al.* 1998; Bo *et al.* 2011c). The aims of this paper are to describe the deep coral assemblages on a large bank located in the Northwestern Sicilian waters (Fig. 1A) and to offer an ecological interpretation of their distribution.

Study Area

The study area, Marco Bank, is situated 17 miles off St. Vito Promontory in the Northwestern part of Sicily (38°16′52″ N, 12°21′59″ E) (Fig. 1A). It is a rocky shoal, NW-SE oriented, arising from a flat bottom around 500 m depth and elevating for about 300 m. The western side of the shoal arises from the bottom, with a steep slope forming a ridge that decreases more gently towards the eastern side. From direct field observations, the flanks of the shoal appear to show different sediment loads on the hardgrounds: the eastern gentle slope, in contrast to the steep western ridge, is more sheltered and the substratum is covered by a film of sediments mixed with organogenic coarse detritus.

This bank is located on the Sicilian continental margin, extending from the northern coast of Sicily to the abyssal plain around Marsili Seamount and repeatedly subjected, on a geological scale, to various subsidence and compressive events (Giorgianni 2011). The oceanographic [illegible] of this area, included in the central Mediterranean region, was clearly identified, on a large spatial scale, by Millot (2005), who reported a dominant W[illegible] flow of all three major water masses, namely, surface Modified Atlantic water, Levantine Intermediate water, and deep Eastern Mediterranean water.

The shoal is severely exploited by professional fishing activities mainly targeted on the red sea-bream *Pagellus bogaraveo* (Brünnich, 1768). Longlines, armed with up to 1000 fishhooks (about 5 km long) and anchored by bricks regularly placed along the line, are used to capture these fishes. An increasingly higher number of recreational boats are seen, too, on these off-shore rocky banks, but no official quantification of the fishing pressure is available.

Material and Methods

Data were collected through a remotely operated vehicle survey (ROV *Pollux*) conducted in September 2011 on board the R/V *Astrea* between 200 and 250 m depth on the top of the bank. The ROV was equipped with a digital camera (Nikon D80, 10 megapixel), a strobe (Nikon SB 400), a high-definition video camera (Sony HDR-HC7), and three jaw grabbers. The ROV hosted a depth sensor, a compass, and two parallel laser beams providing in the video frame a constant 10-cm reference scale for the measurement of the recorded area and size of organisms (height and width of the colonies).

A free internet software (DVDVIDEOSOFT) was used to randomly extract video frames from three ROV bottom video tracks conducted on the top of Marco Bank, respectively along the ridge (track 1) and along the slope (tracks 2 and 3) (Fig. 1B). A total of 108 video-frames (on average 3.5 m^2 each) were considered (48 and 60, respectively, for the ridge and the slope). The overall investigated surface was about 375 m^2 (on a total explored surface of 1500 m^2, respectively 400 m^2 on the ridge and 1100 m^2 on the slope). Frames were analysed with IMAGEJ software to obtain abundance values and percentage cover (± SE) of each megabenthic species examined. To evaluate the impact of fishing activity on the benthic fauna, the number of coral colonies (scleractinians, antipatharians and gorgonians) evidently entangled in lost longlines was counted in each frame.

A one-way ANOSIM was carried out to test for differences in species relative abundance among the megabenthic assemblages of the two investigated areas of Marco Bank (WR, western ridge; ES, eastern slope) considering

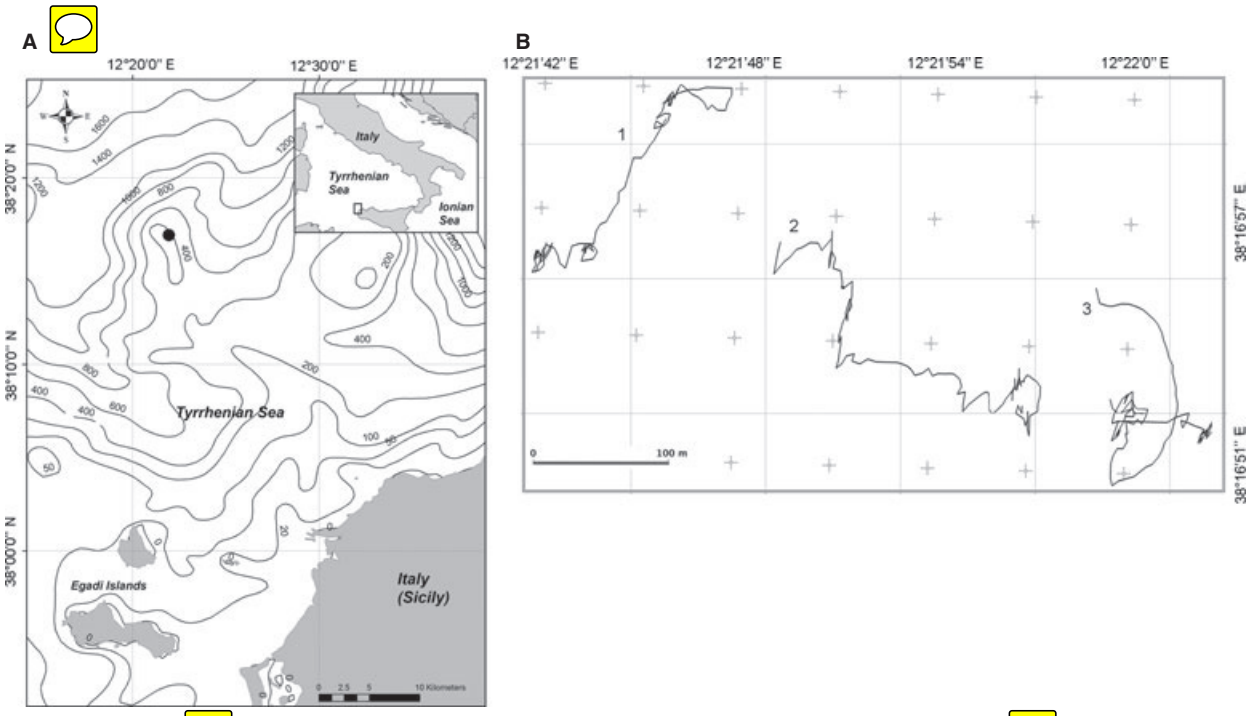

Fig. 1. (A) Location of Marco Bank, NW coasts of Sicily (South Tyrrhenian Sea, Italy). (B) ROV tracks on the top of Marco Bank (with track 1 relative to the ridge and tracks 2 and 3 relative to the slope).

the entire data set [transformed sqr(x) data, Bray–Curtis similarity measure, data distributed homogenously with n = 48 and 60, respectively, for WR and ES]. To identify the taxa explaining the differences between the two areas, a SIMPER analysis was also carried out, based on sqr(x)-transformed data matrix, with a cut-off for low contributions equal to 90%. Finally, to find out whether there was a significant difference in species relative abundance between the two areas of the bank for each considered species, a Mann–Whitney test was performed. Analyses were performed using PAST for Windows version 1.91 (Hammer *et al.* 2001).

Results

Twelve megabenthic species were identified in the video frames: three gorgonian species [*Callogorgia verticillata* (Pallas, 1766), *Viminella flagellum* (Johnson, 1863), *Acanthogorgia hirsuta* Gray, 1857], two antipatharians [*Leiopathes glaberrima* (Esper, 1788) and *Antipathes dichotoma* Pallas, 1766], the scleractinian coral *Dendrophyllia cornigera* (Lamarck, 1816), the parasitic zoanthid tentatively identified as *Isozoanthus primnoidus*, the alcyonacean *Paralcyonium spinulosum* Delle Chiaje, 1822, the sponge *Poecillastra compressa* (Bowerbank, 1866), the crinoid *Leptometra phalangium* (Müller, 1841), sea urchins belonging to the Family Cidaridae, and the brachiopod *Gryphus vitreus* (Born, 1778).

The western ridge of Marco Bank was dominated by a dense meadow of the deep black coral *L. glaberrima* (Figs 2A and 3A–D), together with scattered colonies of *A. hirsuta*, *V. flagellum* and dead corallites of *D. cornigera*. A total of 316 colonies of *L. glaberrima* with a density ranging from 0 to 4.4 colonies m^{-2} (2.3 ± 0.3 on average) were counted in the analysed frames showing an average height of 28.6 ± 2.8 cm, regardless of whether larger specimens, up to 1 m high, were reported in the studied area. The western ridge also hosted numerous specimens of *L. phalangium* (0–30 specimens m^{-2}; 3.4 ± 1.1 on average) and the fan-like sponge *P. compressa* (0–16 specimens m^{-2}; 1.0 ± 0.4 on average). Besides the coral components, the benthic assemblage of this area included specimens of echinoids (0–5 specimens m^{-2}; 1.6 ± 0.2 specimens m^{-2}) and brachiopods (0–5 specimens m^{-2}; 0.4 ± 0.13 on average).

The gently sloping eastern side hosted a dense zoocoenosis of the scleractinian coral *D. cornigera* with a substratum coverage ranging from 0 to 90% (13.8 ± 3.6% on average) (Fig. 3E), high densities of the crinoid *L. phalangium* (0–24 specimens m^{-2}; 5.3 ± 0.7 on average) (Fig. 3F) and several specimens of the brachiopod *G. vitreus* (0–3.3 specimens m^{-2}; 0.43 ± 0.12 on average). In this area the dominant coral species was the large gorgonian *C. verticillata* (Figs 2F and 3G–K) (0–2 colonies m^{-2}; 0.4 ± 0.07 colonies m^{-2}) together with sparse

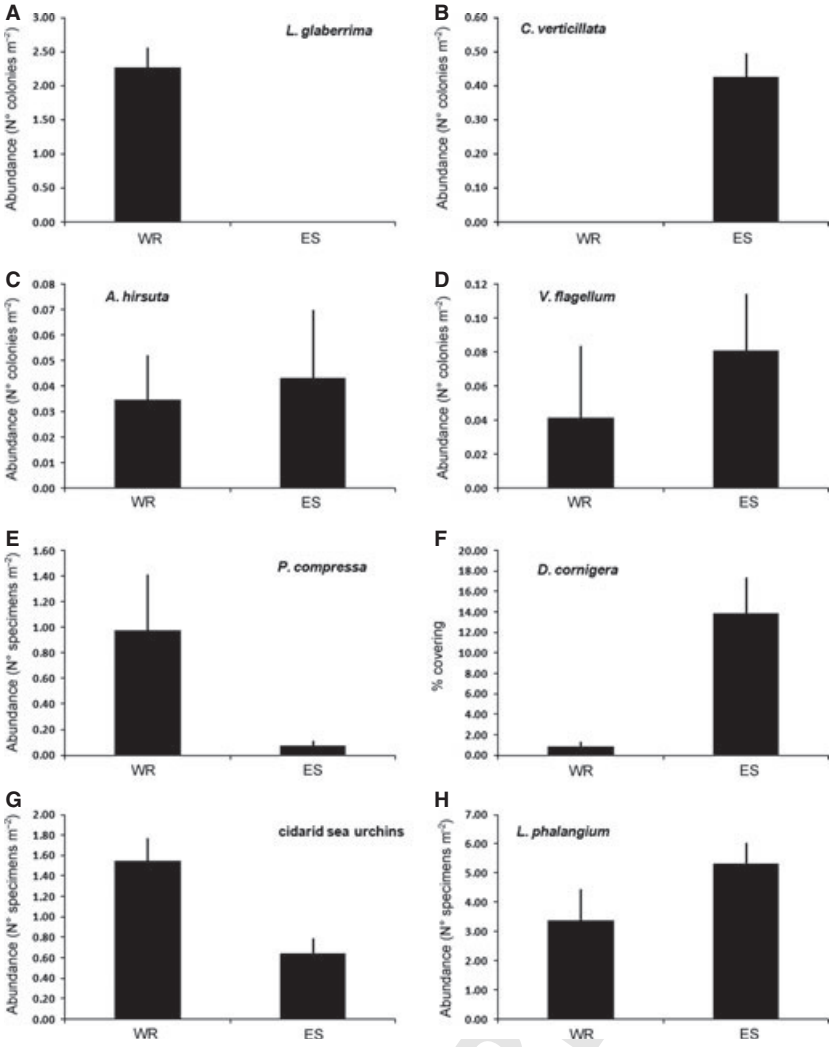

Fig. 2. Mean abundance of the major faunal components of the studied assemblages (number of colonies or individuals per square meter or mean covering percentage ± SE).

colonies of *V. flagellum* (Fig. 3L), *A. hirsuta* (Fig. 3L) and the black coral *A. dichotoma*.

The benthic assemblage settled on the western ridge of the bank is significantly different from that of the eastern slope (one-way ANOSIM, $P < 0.0001$, $R = 0.4888$). Black coral colonies were exclusively found on the western ridge (Fig. 2A) and the large colonies of the sea fan *C. verticillata* were only present on the eastern slope (Fig. 2B). The other two gorgonian species, namely *A. hirsuta* (0.03 ± 0.02 colonies m^{-2} *versus* 0.04 ± 0.02 colonies m^{-2}, respectively for the ridge and the slope) and *V. flagellum* (0.04 ± 0.02 colonies m^{-2} *versus* 0.08 ± 0.03 colonies m^{-2}, respectively), were recorded in both areas but these species did not show significant differences between the two areas (Mann–Whitney, ns) (Fig. 2C and D). No significative distribution pattern was observed for the fan sponge *P. compressa*, which was highly scattered on the rocky bottoms (Fig. 2E) (Mann–Whitney, ns), or for zoanthids, alcyonaceans and brachiopods (Mann–Whitney, ns; data not shown). In contrast, the percentage cover of *D. cornigera* was significatively higher on the eastern slope but was only sporadically observed on the western ridge (Fig. 2F) (Mann–Whitney, $P < 0.001$). Cidarid sea urchins were significatively more abundant on the ridge together with black corals (Mann–Whitney, $P < 0.01$), whereas *L. phalangium* formed a significatively denser aggregation on the slope (Mann–Whitney, $P < 0.001$).

The differences between the benthic assemblages of the western ridge and the eastern slope, following SIMPER analysis, were mostly (87%) due to *L. phalangium* (36%), *D. cornigera* (32%), *L. glaberrima* (13%) and cidarid sea urchins (6%).

Most of the colonies of *C. verticillata* were abundantly covered by epibenthic organisms, in particular by numerous specimens of *L. phalangium* (Fig. 3G–J and M). Four

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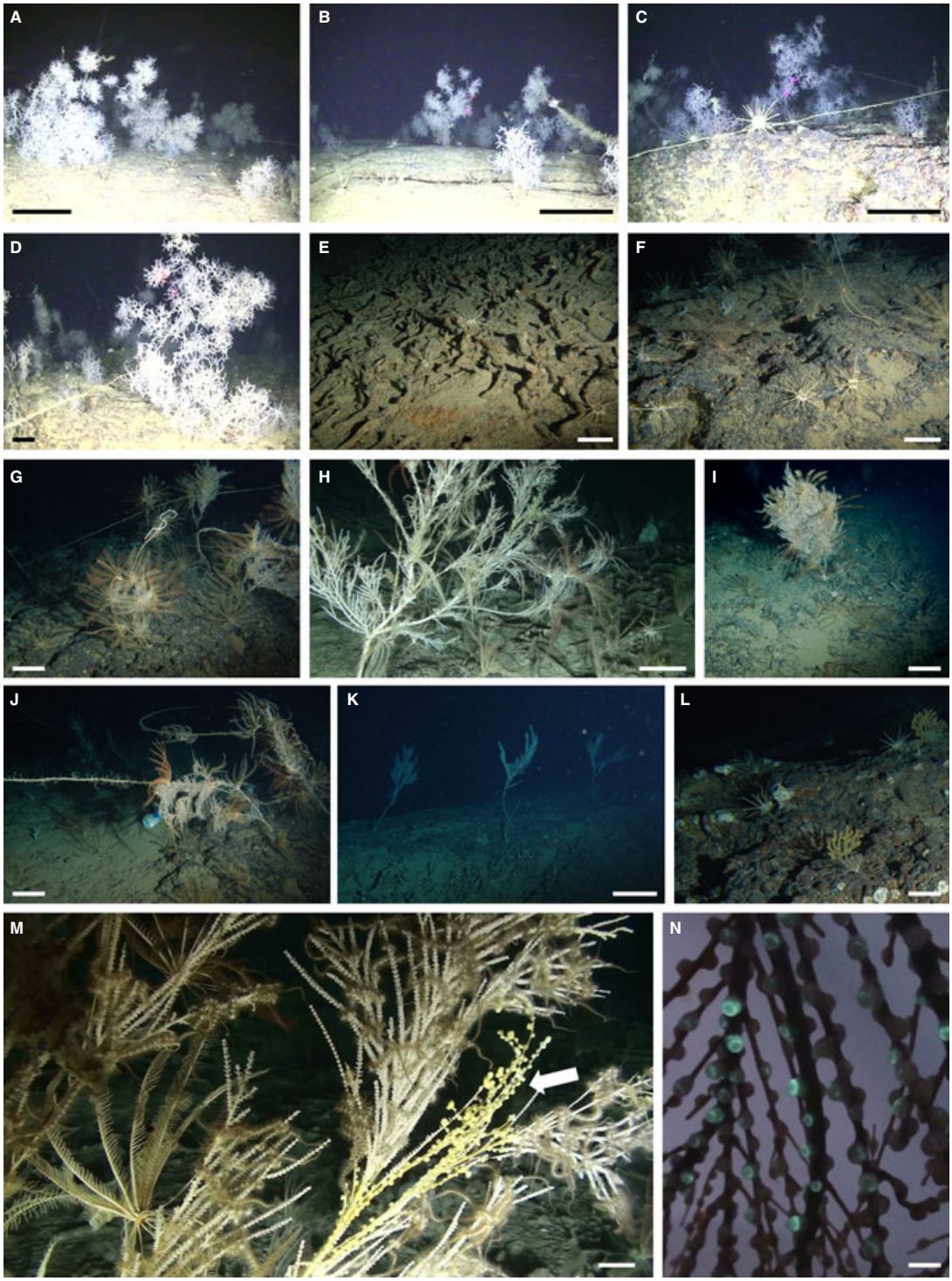

Fig. 3. ROV images of the studied assemblages. (A-D). Dense meadow of *Leiopathes glaberrima*. Numerous longlines are visible entangled in the colonies. (E) Tanatocoenosis of *Dendrophyllia cornigera* and sparse cidarid sea urchins. (F) Bare rock covered with crinoids and hosting sparse colonies of *Paralcyonium spinulosum* and *Viminella flagellum*. (G-K) Colonies of *Callogorgia verticillata* along the eastern slope. Note the broken ramifications of the colonies, the numerous epibiotic crinoids and the abundance of lost fishing lines. (G,H) Multitude of crinoids *Leptometra phalangium* living on substrate and sparse colonies of *Acanthogorgia hirsuta*. Parasitic zoanthid living on *C. verticillata* (white arrow) and close-up view of the bioluminescent polyps. Scale bars: (A,-C,K) 50 cm, (D–J, L) 10 cm; (M) 5 cm; (N) 1.5 cm.

colonies hosted a parasitic zoanthid, tentatively attributed to *Isozoanthus primnoidus* Carreiro-Silva, 2011, yellow- or cream-coloured, which covered wide portions of the gorgonians (Fig. 3M). When mechanically stimulated, the living zoanthid polyps (both underwater and on board) produced an intense green-blue bioluminescence (Fig. 3N) that disappeared after some seconds.

The entire area of the Marco Bank appeared strongly affected by fishing activities (Fig. 3B–D,G,J). Ghost longlines were present everywhere entangled in the branches of the largest coral colonies. Lines stretched on the hardgrounds were entrapped on about 29 ± 6% and 32 ± 3% of the colonies of *L. glaberrima* and *C. verticillata*, respectively. The lost lines had severely damaged the colonies of *C. verticillata*: 100% of the observed colonies had lost the flabellate shape typical of healthy specimens (Fig. 4C, showing a specimen from St. Eufemia, Calabria, South Italy) and showed broken branches (Figs 3K and 4B–C). Conversely, there was no evidence of black coral damage: the majority of the colonies showed the typical arborescent morphology (Figs 3A–D and 4D–E), while some were dead and visible as black skeletons (Fig. 4E), deprived of ramifications but still anchored to the substratum.

Discussion

The studied area facing St. Vito Promontory represents a marine continuum with the Sicily Strait, a hotspot of marine benthic and pelagic biodiversity of the Mediterranean Sea due to its distinctive oceanographic and topographic characteristics (Manzella *et al.* 1988; Bianchi & Morri 2000). A previous ROV footage made by Oceana (2008) in the area of St. Vito Promontory had already revealed rich coral assemblages, in particular a deep seabed dominated by *Leiopathes glaberrima* and a tanatocoenosis of *Dendrophyllia cornigera*.

The benthic assemblages of the investigated deep, offshore Marco Bank is characterized by two significantly distinct assemblages, namely, a black coral and a scleractinian–gorgonian meadow along the western and eastern slopes of the bank, respectively, most likely due to the

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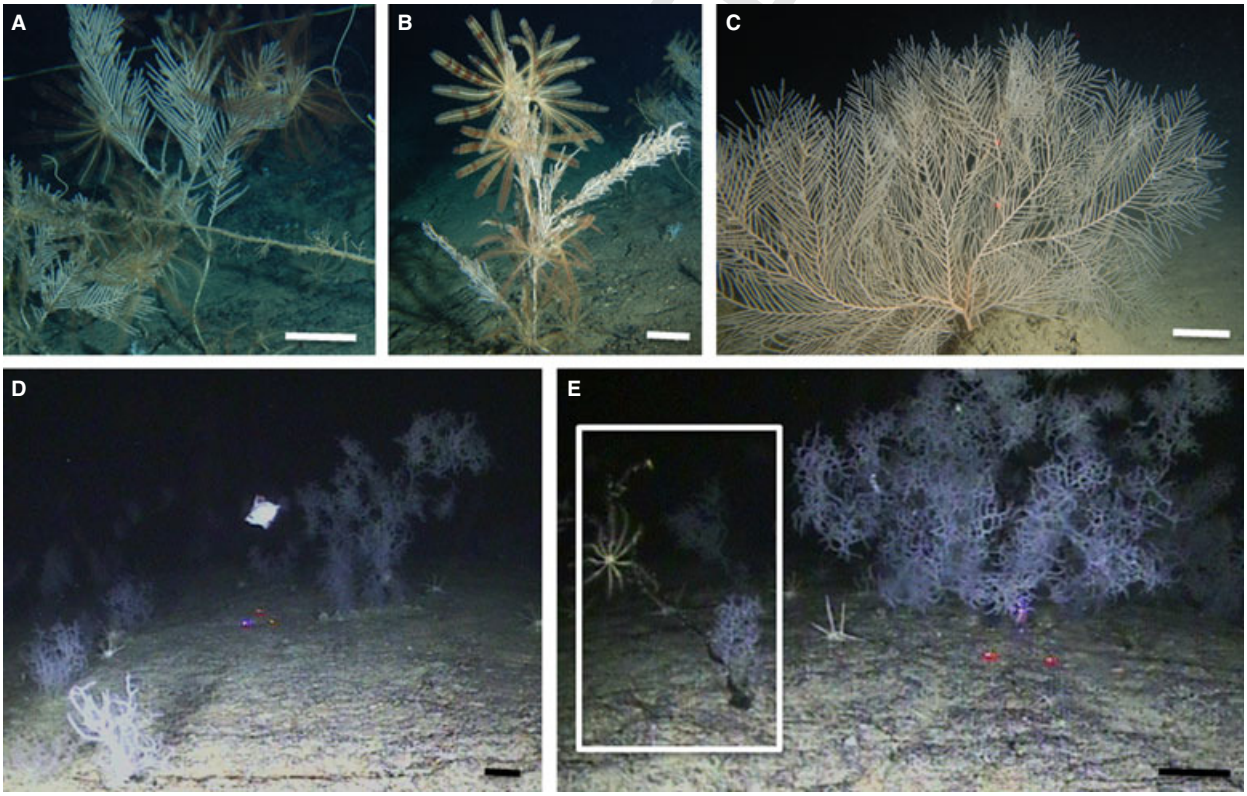

Fig. 4. Impact of longlines on two deep coral species. *Callogorgia verticillata:* (A,B) Damaged specimens showing a small sized, sparsely branched, colonized colony; (C) Healthy colony found on the deep hardgrounds of St. Eufemia (Calabria, South Tyrrhenian Sea). *Leiopathes glaberrima*: (D) Arborescent adult and juvenile colonies not impacted by longlines; (E) Comparison of a healthy and a damaged (white box) colony, the latter characterized by a poorly branched, naked stem. Scale bars: (C-E) 10 cm; (A,B) 5 cm.

influence of different hydrodynamic factors on their distribution (Fig. 5). Although we do not have direct measures of the water flow and sedimentation rates in the study area, differences in the current intensity, hence in silting levels, are evident.

In comparison with the western ridge, the hardgrounds of the eastern slope, probably subjected to weaker currents, are covered by a thick film of sediment, as confirmed by the presence of the sea fan *Callogorgia verticillata*, generally more abundant in sheltered, silted areas (Bo *et al.* 2012). The crinoid *Leptometra phalangium* especially is considered an indicator species of a shelf break (Lavaleye *et al.* 2002) and is generally recorded in highly productive areas in association with important fish stocks (Colloca *et al.* 2004). In the Mediterranean Sea, aggregations of *L. phalangium* have been reported in several localities characterized by sandy or detritic bottoms, where they always show high abundances (10–15 specimens m^{-2}, Colloca *et al.* 2004; Taviani *et al.* 2010). In particular, numerous specimens (34 ± 3.3 specimens m^{-2}) have been described as forming a dense facies at the base of the pinnacle of the Vercelli Seamount, likely filtering the particulate organic matter sinking from the overlaying coral assemblage (M. Bo, pers. obs.). *Callogorgia verticillata* has also been reported as a typical component of the silted, deep rocky or detritic bottoms (Carpine & Grasshoff 1975; Bo *et al.* 2011b) being too tall and fragile to live in areas characterized by strong currents. In contrast, the elevated rocky ridge, located on the western side of the bank, is dominated by the tall colonies of *L. glaberrima*, which tends to avoid silting and exploit the predominant current. This species is among the least known of the Mediterranean basin (Opresko & Försterra 2004) due to its deep bathymetric range; however, recent observations have indicated that this black coral is one of the major anthozoan components in deep rocky environments (Ocean... 2008; Deidun *et al.* 2010; Mastrototaro *et al.* 2010; Bo *et al.* 2011c), where it may form very dense aggregations, whose ecological role has not as yet been investigated.

The presence of the meadow of *L. glaberrima* in the most exposed area of the Marco Bank confirms the general preference of the tallest black coral species for energetic habitats. *Antipathella subpinnata* (Ellis & Solander, 1896), for example, a tall and arborescent species similar to *L. glaberrima*, was described on a shoal close to Favazzina (South Calabria, Tyrrhenian Sea), where it was mainly distributed on the flanks receiving the out-flowing tidal stream of the Messina Strait (Bo *et al.* 2009). Black corals are usually related to water movement; high abundances of antipatharian colonies, in fact, are typically reported in areas where the surrounding topography accelerates currents, such as on the crest of seamounts, pinnacles and knobs (Genin *et al.* 1986; Bo *et al.* 2011c; Wagner *et al.* 2012).

The other two anthozoan components of the assemblage, *Acanthogorgia hirsuta* and *Viminella flagellum*, do not occur frequently on the Marco Bank. These species usually occur on lightly silted rocky substrates and are often observed together with other anthozoan species (Carpine & Grasshoff 1975; Giusti *et al.* 2012), including *C. verticillata* (Brito & Ocaña 2004), suggesting a certain adaptability to various environmental conditions of this species. In particular, populations of *V. flagellum* are known to have a patchy distribution, alternating dense

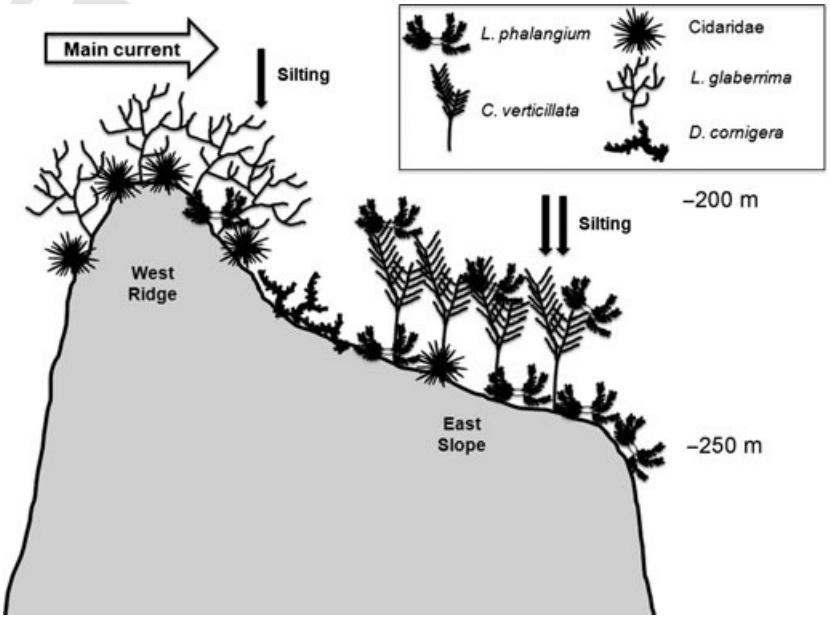

Fig. 5. Zonation of the megabenthic assemblages. The figure schematizes the distribution of the most conspicuous and abundant components of the megafauna dwelling at about 200–250 m depth on the top of the bank. Two distinct facies are well represented, one dominated by a black coral population of *Leiopathes glaberrima* on the western ridge and one by *Callogorgia verticillata* on the eastern slope. The two areas are separated by a gentle decline dominated by a tanatocoenosis of *Dendrophyllia cornigera*.

meadows with sparse colonies (Grasshoff 1972). This is the second sighting of this species in Italian waters after its recent record on a deep rocky cliff of Pantelleria Island (Sicily Strait) (Giusti *et al.* 2012).

The observations conducted on the Marco Bank highlight a major fishing impact on the benthic assemblages, expressed as direct damage on about 30% of the arborescent coral colonies. The deep Mediterranean rocky structures are often elected as fishing grounds by longline fisheries. Unfortunately, it is impossible to obtain data about the number of vessels fishing on the Marco Bank, due to the contemporaneous activity of professional and recreational fishermen. Moreover, due to its position outside the Italian National waters, the bank is exploited by numerous foreign vessels. The result is a major information gap on the impact of longline fisheries widely recognized to have a long-term impact on the megabenthic long-lived and slow-growing arborescent fauna (Bavestrello *et al.* 1997; Roberts 2002; Mortensen & Buhl-Mortensen 2004; Mortensen *et al.* 2005; Lumsden *et al.* 2007; Bo *et al.* 2009, 2011c; Cupido *et al.* 2009; Orejas *et al.* 2009; Deidun *et al.* 2010; Tsounis *et al.* 2012; Pr[illegible]*et al.* 2013).

The observed corals show variable susceptibility to the mechanical impact of bottom lines, with *C. verticillata*, in particular, being the most vulnerable. This species is commonly found on flat or gently sloping hardgrounds below 120 m depth (Bo *et al.* 2011b,c). This feature makes *C. verticillata* particularly vulnerable to the fishing activities conducted on these bottoms, representing, on the basis of grey literature, one of the most common coral bycatches of the Mediterranean fisheries. The vulnerability of this primnoid gorgonian is due to its large size, erect development and, particularly, its brittle skeleton (Carpine & Grasshoff 1975), which makes it more easily breakable than flexible organic skeletons, as evidenced by the presence of laxly ramified colonies. In contrast, the colonies of *L. glaberrima*, characterized by a chitinous skeleton, are not as easily damaged as the colonies of *C. verticillata*, despite the similar occurrence of entangled specimens. It appears, on the basis of our observations, that the mechanical friction on this black coral due to entrapped lines damages the tissues of its branches, which, being more flexible, take a longer time to be broken down. The basal stem, measuring several cm in diameter, may persist for a very long period.

Among the impacted corals, *C. verticillata* is also one of the most colonized by epibionts (Bo *et al.* 2011c). The degree of colonization seems related to the level of mechanical damage inflicted on the colonies, as hypothesized also for the colonies of *C. verticillata* living on deep Atlantic banks that are subjected to a high fishing pressure (Carreiro-Silva *et al.* 2011). The recorded bioluminescent zoanthid is a new species for the Mediterranean fauna. Zibrowius & Taviani (2005) reported a bioluminescent undescribed zoanthid associated to a sponge and a dead solitary scleractinian; however, we have tentatively attributed this species to the recently described Atlantic *Isozoanthus primnoidus* epibiont of *C. verticillata* (Carreiro-Silva *et al.* 2011). No bioluminescence was observed in the Atlantic specimens, probably as a result of collection and fixation procedures.

The record of this large, spectacular coral species highlights once more that Mediterranean deep rocky shoals are reservoirs of undescribed biodiversity. However, it is evident that the fishing impact strongly affects the deep assemblages even before they are studied. Conservation programs, in line with the European Community (EC no. 1967/2006) indications about priority habitats such as the deep circa-littoral rocky shelf, cannot be delayed if these deep biodiversity oases are to be preserved (Bo *et al.* 2012).

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