Animal Forests in Deep Coastal Bottoms and Continental Shelf of the Mediterranean Sea

Andrea Gori, Giorgio Bavestrello, Jordi Grinyó, Carlos Dominguez-Carrió, Stefano Ambroso, and Marzia Bo

Abstract

Several studies using Remotely Operated Vehicles and manned submersibles have recently provided quantitative information on animal forests dominated by gorgonians, black corals, and sponges dwelling at 40–200 m depth in the Mediterranean Sea. These assemblages have received relatively little attention during the last decades due to the fact that they are found below scuba diving depths, and most submersible-based research has been traditionally conducted below 200 m depth. However, these communities are among the most threatened by the impact of fishing pressure, since the larger proportion of fishing activities, especially bottom trawling on soft bottoms and passive gears on hard grounds, concentrate between 50 and 200 m depth. This chapter reviews the recent advances in the study of the spatial and bathymetric distribution patterns of these animal forests, their species composition, ecology, and conservation status.

Keywords

Gorgonian • Black corals • Sponges • ROV • Manned submersibles • Mediterranean Sea

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1 Exploration of Hard Bottoms at Intermediate Depths in the Mediterranean Sea

Knowledge about coastal benthic communities has greatly increased during the last decades mainly thanks to the wide diffusion of scuba diving, allowing observation and sampling of rocky bottoms located from the shoreline down to around 40 m depth or deeper in the case of technical diving. Similarly, deep areas located under 200 m depth have been explored in the last decades by means of Remotely Operated Vehicles (ROVs) and manned submersibles. However, marine communities located on hard-bottom substrates at intermediate depths (40–200 m depth) have received relatively little attention (Sink et al. 2006).

In the Mediterranean Sea, the first scientific observations of the hard-bottom communities located at 40–200 m depth can be dated back to the 1950s, performed as marginal target of the first manned submersible explorations mainly focused on the exploration of much deeper areas. The bathyscaphs *FNRS III* and *Trieste*, developed by the visionary Swiss engineer Auguste Piccard, performed several dives in the western Mediterranean Sea (e.g., Gulf of Lions, Gulf of Naples, the Ponza Archipelago) at depths ranging from 100 to 2,800 m (Martin 1960). Although these early explorations were mainly focused on plankton studies, a major descriptive effort was also made on the benthic communities, and the amount of collected data was such that the results still represent the main reference for the bionomic zonation of the Mediterranean Sea (Pérès and Picard 1964). The development, in

1959, by the French explorer Jacques Cousteau of the manned submersible *soucoupe plongeante*, together with the great improvement of photographic equipment thanks to Cousteau and Harold Edgerton (Laban et al. 1963), made possible throughout the 1960s and 1970s detailed descriptions of the explored sea bottoms accompanied by a rich collection of black and white pictures. Numerous localities of the Mediterranean Sea were in this way explored between 70 and 400 m depth, mostly in the northwestern basin (e.g., Vaissière and Carpine 1964; Reyss and Soyer 1965). The photographic footage of these habitats clearly reported for the first time the occurrence of dense animal forests made of gorgonians, corals, and black corals accompanied by numerous sponges, crinoids, brachiopods, and bryozoans, which could dominate both the soft and hard bottoms over the continental shelf (Laban et al. 1963; Vaissière and Carpine 1964).

However, it was not until the last decade that the development of ROVs, manned submersibles, and technical diving equipment at more affordable operational costs increased their accessibility for marine ecologists. This has made possible a wide series of investigations, especially focused on the benthic communities dwelling in deep coastal bottoms and continental shelves of the Mediterranean Sea. Deep sublittoral coastal bottoms from 40 to 80 m depth were recently explored by ROVs and technical divers along the Catalan (Rossi et al. 2008; Gori et al. 2011a; Ambroso et al. 2014; Coppari et al. 2016) and the Liguro-Provencal coasts (Cerrano et al. 2010; Di Camillo et al. 2013; Fabri et al. 2014). ROVs and manned submersibles (Fig. 1) were also used to explore and characterize the hard-bottom communities located at 80–200 m depth on several areas of the continental shelf and shelf edge of the Catalan coast (Orejas et al. 2009; Gili et al. 2011; Gori et al. 2013; Dominguez-Carrió 2017), the Balearic Islands (Requena and Gili 2014; Grinyó et al. 2016a), as well as the Sicily Channel and the Ligurian, Tyrrhenian, and Ionian seas (Bo et al. 2009, 2011a, 2011b, 2012, 2014a, b, 2015; Angiolillo et al. 2012, 2015; Giusti et al. 2012; Priori et al. 2013; Cau et al. 2015). Deep coastal areas and rocky shoals and soft bottoms located at intermediate depths were also recently explored in the eastern Mediterranean Sea (Salomidi et al. 2009; Orejas et al. pers. com.) also by the analysis of the benthic fishery bycatch (Deidun et al. 2010; Mytilineou et al. 2014).

2 Animal Forests at 40–200 m Depth in the Mediterranean Sea

Gorgonians and black corals are among the main structuring species in the Mediterranean animal forests located in deep coastal areas and on the continental shelf. Gorgonians are the best-represented megabenthic species (more than 20 species), inhabiting a wide range of environments in the Mediterranean Sea (Carpine and Grasshoff 1975). Morphology and dimension vary widely from one species to another, from a few centimeters to more than 1.5 m high. Gorgonians form dense monospecific or multispecific assemblages that can extend over large areas (Gori et al. 2011a; Grinyó et al. 2016a). Black corals are less diverse than gorgonians in the

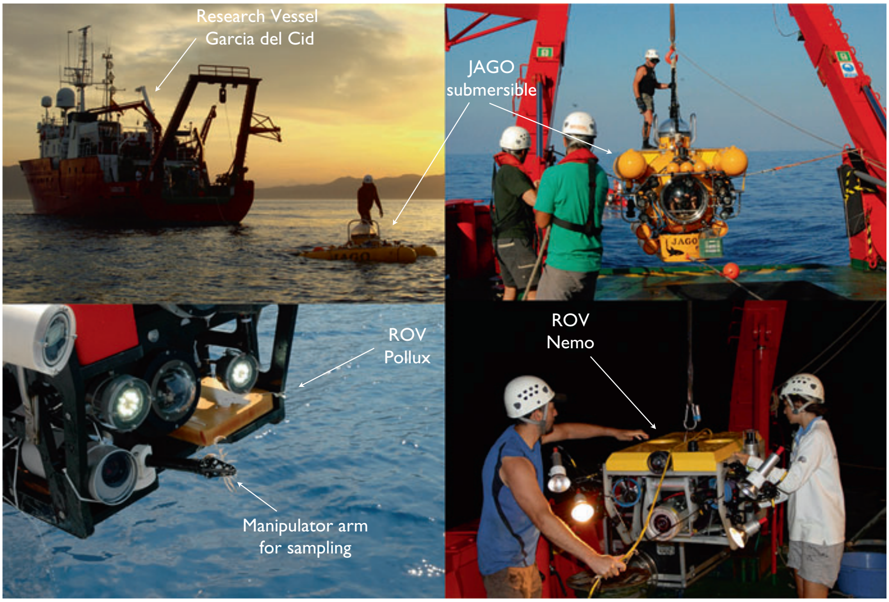

Fig. 1 ROVs and a manned submersible recently used to explore gorgonian and black coral assemblages at 80–200 m depth in the Mediterranean Sea; (*up left*) surveys in Cap de Creus and (*up and down right*) Menorca Channel using the submersible JAGO (IFM-GEOMAR) and the ROV Nemo (Gavin Newman) (*photos by Andrea Gori*); (*down left*) the ROV Pollux (ISPRA) (*photo by Federico Betti*)

Mediterranean Sea, where five species have been reported (Bo et al. 2009). Some species are often found associated to deep gorgonian assemblages, but more often they are the dominant species in multispecific assemblages (Bo et al. 2014a, 2015) with an overall deeper bathymetric distribution than most of the large, structuring gorgonian species (Bo et al. 2009). Black corals are extremely longevous and slow-growing organisms; therefore, presence of large colonies is an indicative of well-preserved environments (Bo et al. 2015). Finally, *Errina aspera* is the only hydrocoral species (stylasterid) in the Mediterranean Sea, reaching dimensions up to ~20 cm under strong hydrodynamic conditions in the Messina and Gibraltar straits (Salvati et al. 2010).

2.1 Deep Coastal Assemblages

Mediterranean shallow coastal gorgonians and other coral species have been recently shown to have a wider bathymetric distribution than previously thought and to form dense assemblages in deep coastal rocky bottoms located below 40 m depth. Indeed, the highest abundances of the gorgonians *Eunicella singularis* and *Paramuricea*

Fig. 2 Map of the Mediterranean Sea with the position of the explored gorgonian and black coral assemblages at 40–200 m depth (*in bold are the case studies highlighted in the text*)

clavata in the Cap de Creus area, along the Catalan coast (NW Mediterranean) (Figs. 2 and 3), were observed at 15–70 m and 25–50 m depth, respectively (Gori et al. 2011a). Deep coastal rocky bottoms are also characterized by high densities of the soft coral *Alcyonium acaule* (Ambroso et al. 2014) and the treelike sponge *Axinella polypoides* (Coppari et al. 2016) as typical component of the coralligenous community (Gili et al. 1989; Ballesteros 2006) (Table 1). Similarly, the gorgonians *P. clavata*, *Eunicella cavolinii*, and *Corallium rubrum* have been shown to dominate the coastal coralligenous bottoms at 55–120 m depth in the Gulf of Naples (Fig. 2) in the Tyrrhenian Sea (Angiolillo et al. 2015), as well as the coastal rocky bottoms up to 80 m depth at Pantelleria Island in the Sicily Channel (Fig. 2), together with some sparse colonies of the gold coral *Savalia savaglia* (Angiolillo et al. 2012) (Table 1). A dense population of this gold coral was observed together with *P. clavata*, *E. cavolinii*, and *Eunicella verrucosa* at ~70 m depth near the base of the cliff of the Portofino Promontory (Fig. 2) in the Ligurian Sea (Cerrano et al. 2010), where, in surrounding mud bottom, a dense population of the large-sized hydrozoan *Lytocarpia myriophyllum* was also observed (Cerrano et al. 2015) (Table 1). The black coral *Antipathella subpinnata* has been often found associated with *P. clavata* and *E. cavolinii* in coastal rocky bottoms at ~50–100 m depth in several localities in the Ligurian and Tyrrhenian Sea (Bo et al. 2008). Gorgonian assemblages were recently also reported in the deeper part of the volcanic island of Pantelleria (Fig. 2), which is the emergent summit of a large submarine edifice elevating over an oceanic crust. Sparse colonies of the gorgonian *Ellisella paraplexauroides* were observed on the hard substrate at 80–94 m depth, below the distribution limit of *P. clavata* and *E. cavolinii* (Angiolillo et al. 2012) (Table 1). Finally, in the eastern Mediterranean basin (Fig. 2), coastal gorgonian assemblages are rarely observed shallower than 40 m depth, and the mean distribution depth is ~60 m for *P. clavata* and *E. cavolinii*, which are the most widespread species on coralligenous, together with several sponges, bryozoans, and the gold coral *S. savaglia* (Salomidi et al. 2009) (Table 1).

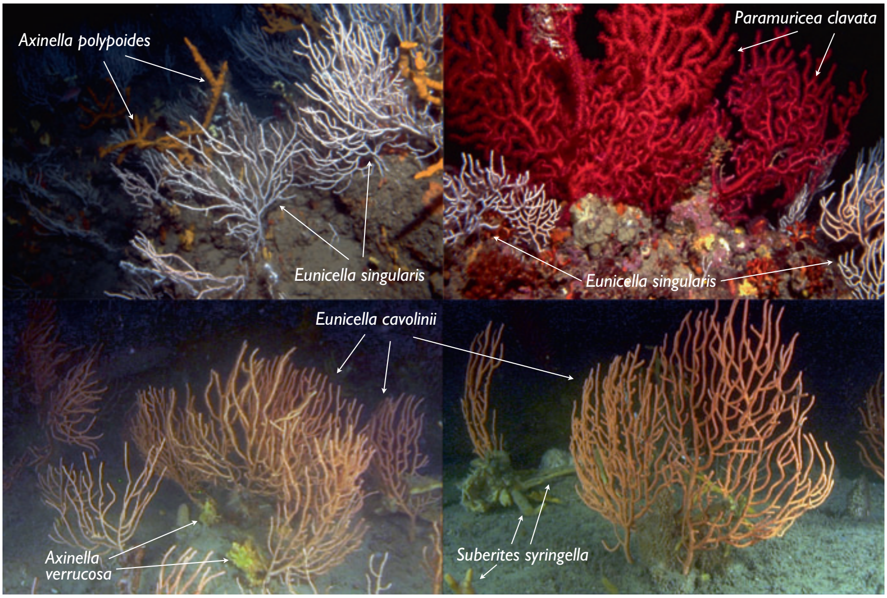

Fig. 3 Cap de Creus. Surveys "Coral Rojo" and "Life Indemares" in Catalonia supported, respectively, by Generalitat de Catalunya and European Union, 2003–2012 (60–100 m depth)

2.2 Continental Shelf Assemblages

Deeper, coralligenous bottoms at 50–80 m depth on the continental shelf have been observed to host populations of the precious red coral *C. rubrum* together with *P. clavata* and *E. cavolinii* in the Elba Island (Fig. 2) (Priori et al. 2013; Angiolillo et al. 2015) with the common presence of the soft corals *A. acaule*, *Paralcyonium spinulosum*, and *Alcyonium coralloides* overgrowing dead gorgonians and some colonies of the black coral *A. subpinnata* (Angiolillo et al. 2015) (Table 1). Similarly, in the Menorca Channel (Figs. 2 and 4) coralligenous banks at 40–70 m depth host populations of *P. clavata* and *E. singularis*, with lower densities than in shallower waters, but with a dominance of large colonies; deeper banks host instead high densities of *E. cavolinii*. In this area, the maërl bottoms are characterized by extensive high-density assemblages of the gorgonian *Paramuricea macrospina* (Grinyó et al. 2016a) (Table 1).

At similar depths, but under lower light conditions due to higher turbidity, hard bottoms on the continental shelf support high densities of the gorgonian *E. cavolinii* together with several sponges (e.g., *Suberites syringella*) in the Cap de Creus area (Figs. 2 and 3) (Dominguez-Carrió 2017). Likewise, the same treelike gorgonians *E. cavolinii*, *P. clavata*, *C. rubrum*, *P. macrospina*, *Callogorgia verticillata* (Bo et al. 2012), the black coral *Antipathes dichotoma* (Bo et al. 2011b), and a rich sponge fauna (Bertolino et al. 2015) are characteristic of the "*roche du large*" community located at 70–130 m depth in the Gulf of St. Eufemia (Figs. 3 and 5, and Table 1).

The black coral *A. subpinnata* forms dense assemblages together with *P. clavata* and sparse colonies of *E. cavolinii* on the top (50–70 m depth) of two rocky pinnacles that arise from the continental shelf at 50–100 m depth near Favazzina (Fig. 2, and Table 1). *A. subpinnata* extends deeper to 90 m, while gorgonians reduce with increasing depth and are completely absent at 90 m depth (Bo et al. 2009). Finally, dense assemblages of the hydrocoral *E. aspera*, with colonies up to 15–30 cm high, have been observed to develop on rocky shoals and coralligenous bottoms under the strong current conditions characteristics of the Strait of Messina (Fig. 2) (Giacobbe et al. 2007; Salvati et al. 2010) (Table 1).

Soft corals and sea pens are the main megabenthic species in soft bottoms of the continental shelf, where they can form high-density assemblages. *Veretillum cynomorium* and *Alcyonium palmatum* are soft corals dominating the soft bottoms surrounding coralligenous banks and boulders at 60–90 m depth on the continental shelf near the Elba Island (Fig. 2 and Table 1) (Angiolillo et al. 2015). The sea pen *Pteroeides spinosum* occurs at 30–160 m depth on the sandy-muddy bottoms of the Giardini Naxos Gulf (Fig. 2) with the higher densities concentrated at 50–90 m depth, where they probably find optimal conditions and food availability (Porporato et al. 2014) (Table 1).

2.3 Shelf Edge and Upper Slope Assemblages

The shelf edge is the transition zone between the continental shelf and the continental slope (at 110–200 m depth in the Mediterranean, depending on the area). Gorgonian, black corals, and sponges colonize the infrequent and highly localized rocky outcrops that occur on the shelf edge (Bo et al. 2015; Cau et al. 2015; Grinyó et al. 2016a). Gorgonian diversity is much higher on the shelf edge than in coastal areas or on the continental shelf, with several species commonly occurring in multispecific assemblages. In the Menorca Channel (Figs. 2 and 4), these assemblages are dominated by the gorgonian *E. cavolinii*, *Swiftia pallida*, *Viminella flagellum*, and *C. verticillata*, together with lower densities of *P. macrospina*, *Acanthogorgia hirsuta*, *Bebryce mollis*, and *C. rubrum* (Grinyó et al. 2016a). The black corals *A. subpinnata*, *A. dichotoma*, and *L. glaberrima* occur at low density within these assemblages, and vertical rocky cliffs are largely covered by encrusting sponges of the genus *Haliclona* together with fanlike sponges such as *Poecillastra compressa* (Requena and Gili 2014). Among gorgonians, only *B. mollis*, *S. pallida*, *V. flagellum*, and *C. verticillata* were observed to extend their distribution below 200 m depth, in mainly monospecific assemblages with low densities (Grinyó et al. 2016a) (Table 1).

Rich gorgonian and black coral assemblages were also recently reported on pinnacles at 120–170 m depth (Cau et al. 2015) along the South Sardinia continental margin (Fig. 2). The gorgonian *C. verticillata* generally dominates on gently sloping silted rocky bottoms, and *C. rubrum* dominates on the highly sloping rocky walls without sediments with densities up to 64 col. m^{-2}. When the bottom morphological complexity increases and the silt coverage is highly variable, the gorgonian

E. cavolinii, *A. hirsuta*, and *V. flagellum* accompanied *C. verticillata* (Cau et al. 2015). Similarly to the Menorca Channel (Grinyó et al. 2016a), black corals were less abundant than gorgonians in these assemblages, with *Paranthipates larix*, *A. subpinnata*, *A. dichotoma*, and *L. glaberrima* occurring at low density in the areas more covered by silt (Cau et al. 2015) (Table 1). Conversely, black corals mainly dominate the assemblages occurring on the deeper rocky shoals located on the upper continental slope. Dense forests of the black coral *L. glaberrima* were recently reported at 180–200 m depth in the Carloforte Shoal (Bo et al. 2015), where numerous rocky elevations emerge from a flat muddy bottoms at about 200 m depth on the southwest continental margin of Sardinia (Figs. 2 and 6). The black corals *A. dichotoma*, *P. larix*, and the gorgonians *C. verticillata*, *A. hirsuta*, *E. cavolinii*, and *B. mollis* were also present with low abundances (Bo et al. 2015) (Table 1). Large colonies (~1 m in average height) of the bottle-brush black coral *P. larix* occur in small patches (~4 colonies m^{-2}) on the rocky outcrops of two rocky shoals located southeast of the island of Montecristo (Tuscan Archipelago, Tyrrhenian Sea) between 100 and 200 m depth (Bo et al. 2014a), as well as on the rocky boulders interspersed within the soft sediments of the continental slope of the Pontine Islands (Fig. 2) together with *L. glaberrima* and *A. dichotoma* (Ingrassia et al. 2016) (Table 1).

The muddy bottoms at ~200 m depth surrounding the rocky terraces of the Carloforte Shoal (Figs. 2 and 6) hosted a dense meadow of large colonies of the bamboo coral *I. elongata* (Bo et al. 2015) (Table 1), which is the main treelike species in deep bathyal muds (Cartes et al. 2013).

2.4 Assemblages in Offshore Banks and Seamounts

The few Mediterranean banks and seamounts that have been so far explored regarding the benthic communities showed similar dense gorgonian and black coral assemblages in their shallower areas. The Vercelli seamount (Fig. 2) arises from the muddy sea bottom at about 2,000 m, with steep walls characterized by isolated rocky concretions. At 200–250 m depth, walls turn into sand flat bottoms gently sloping up to about 100 m depth, where a rocky peak rises reaching its maximal elevation at ~60 m depth hosting dense coralligenous assemblages dominated by the gorgonians *P. clavata* and *E. cavolinii* (Bo et al. 2011a). Rocky bottoms close to the detritic bottom of this peak (90–100 m depth) present dense assemblages of the gorgonian *E. cavolinii* together with few colonies of *P. clavata*, the sponges *Axinella verrucosa* and *Axinella damicornis*, scattered colonies of the gorgonians *C. verticillata* and *C. rubrum*, the scleractinian *Dendrophyllia cornigera*, and the black coral *A. subpinnata*. In the shallower area (70–90 m depth), the density of *P. clavata* progressively increases toward the surface, whereas that of *E. cavolinii* decreases, and the soft coral *P. spinulosum* was frequently observed (Bo et al. 2011a) (Table 1). Similarly, the Marco Bank, situated off the northwestern coast of Sicily (Fig. 2), is a rocky shoal arising from a flat bottom around 500 m depth, whether its top remains deeper (~200 m depth) than that of the Vercelli seamount. Elevated

Table 1 Bathymetric distribution of the main megabenthic species of marine animal forests in (2.1) deep coastal areas, (2.2) continental shelf, (2.3) shelf edge and upper slope, and (2.4) offshore banks and seamounts in the Mediterranean Sea (data from the literature quoted in the text)

Species	2.1 Deep coastal areas	Depth (m)	2.2 Continental shelf	Depth (m)	2.3 Shelf edge and upper slope	Depth (m)	2.4 Offshore banks and seamounts	Depth (m)
Ellisella paraplexauroides (gorgonian)	Pantelleria	80–94						
Eunicella verrucosa (gorgonian)	Portofino	~70	Mantice Shoal	70–150				
Eunicella singularis (gorgonian)	Cap de Creus, Eastern Mediterranean	6–67 45–50	Menorca Channel	52–88				
Eunicella cavolini (gorgonian)	Eastern Mediterranean, Gulf of Naples, Portofino, Pantelleria	30–120 55–120 ~70 ~80	Favazzina, Elba, Cap de Creus, Gulf of St. Eufemia, Mantice Shoals	55–80 50–80 70–120 70–130 70–150	Menorca Channel, Montecristo Shoals, South Sardinia, Carloforte Shoal, Cap de Creus	94–200 100–200 120–170 186–200 87–280	Vercelli Seamount, St. Lucia Bank	70–100 140–180
Corallium rubrum (gorgonian)	Cap de Creus, Phlegraean islands, Amalfi coast, Eastern Mediterranean, Pantelleria, Gulf of Naples	45–85 50–130 50–120 60–65 ~80 110–140	Elba, Menorca Channel, Gulf of St. Eufemia	50–80 80–120 70–130	Montecristo Shoals, Cap de Creus, South Sardinia	100–200 125–225 120–170	Vercelli Seamount	70–100
Paramuricea clavata (gorgonian)	Cap de Creus, Eastern Mediterranean, Portofino, Pantelleria	15–62 30–120 ~70 ~80	Favazzina, Elba, Menorca Channel, Gulf of St. Eufemia, Mantice Shoal	55–80 50–80 67–92 70–130 70–150	Menorca Channel, Montecristo Shoals	109–120 100–200	Vercelli Seamount	70–100
Paramuricea macrospina (gorgonian)			Menorca Channel, Gulf of St. Eufemia	65–100 70–130	Menorca Channel	100–160	Vercelli Seamount	70–100
Callogorgia verticillata (gorgonian)			Gulf of St. Eufemia	70–130	Menorca Channel, South Sardinia, Carloforte Shoal, Montecristo Shoals	112–348 120–170 186–200 100–200	Vercelli Seamount, Palmarola Seamount, Marco Bank, Malta	70–100 194–220 200–280 300–400
Bebryce mollis (gorgonian)			Gulf of St. Eufemia	130	Montecristo Shoals, Menorca Channel, South Sardinia, Carloforte Shoal	100–200 112–347 120–170 186–200	St. Lucia Bank, Malta	140–210 250–400
Viminella flagellum (gorgonian)					Montecristo Shoals, Menorca Channel, South Sardinia, Pantelleria	100–200 124–225 120–130 156–242	Marco Bank, Malta	200–250 150–400

(*continued*)

Table 1 (continued)

Species	2.1 Deep coastal areas	Depth (m)	2.2 Continental shelf	Depth (m)	2.3 Shelf edge and upper slope	Depth (m)	2.4 Offshore banks and seamounts	Depth (m)
Acanthogorgia hirsuta (gorgonian)					South Sardinia, Menorca Channel, Carloforte Shoal	120–145 149–176 186–200	Marco Bank	200–250
Swiftia pallida (gorgonian)					Menorca Channel, Pantelleria	102–347 156–242	Malta	150–240
Villogorgia bebrycoides (gorgonian)					South Sardinia	120–170	St. Lucia Bank	140–210
Isidella elongata (bamboo coral)					Carloforte Shoal	~210		
Antipathella subpinnata (black coral)	Pantelleria	70–100	Elba, Capo Comino, Stromboli, S. Flavia, Favazzina, Bordighera, Capraia, Capo Mele, Portofino, Gulf of St. Eufemia	50–80 54 52–58 55–65 55–100 64–75 75–90 80 100 70–130	Mantice Shoal, South Sardinia, Menorca Channel, Montecristo Shoals	70–150 120–170 133–181 100–200	Vercelli Seamount, St. Lucia Bank, Malta	70–100 180–210 100–400
Antipathes dichotoma (black coral)			Gulf of St. Eufemia	70–130	Menorca Channel, Montecristo Shoals, South Sardinia, Pontine Islands, Carloforte Shoal	92–187 100–200 120–170 145–155 186–200	St. Lucia Bank, Marco Bank	140–210 200–250
Parantipathes larix (black coral)			Gulf of St. Eufemia	70–130	South Sardinia, Pontine Islands, Montecristo Shoals, Carloforte Shoal	120–170 130–155 100–200 186–200	St. Lucia Bank, Palmarola Seamount	140–210 194–220
Leiopathes glaberrima (black coral)					Montecristo Shoals, South Sardinia, Pontine Islands, Vedove Shoal, Carloforte Shoal, Menorca Channel	100–200 120–130 145–155 160–200 186–200 180–290	St. Lucia Bank, Palmarola Seamount, Marco Bank, Malta	180–210 194–220 200–280 250–400
Alcyonium acaule (soft coral)	Cap de Creus	16–67	Elba	50–80				
Alcyonium palmatum (soft coral)	Cap de Creus	28–60	Elba, Gulf of St. Eufemia, Cap de Creus	60–90 70–130 85–140	Menorca Channel, Cap de Creus	99–130 140–187	Vercelli Seamount	70–100
Paralcyonium spinulosum (soft coral)			Elba	50–80	Cap de Creus Menorca Channel	85–280 100–176	Vercelli Seamount, Marco Bank	70–100 200–250

(*continued*)

Table 1 (continued)

Species	2.1 Deep coastal areas	Depth (m)	2.2 Continental shelf	Depth (m)	2.3 Shelf edge and upper slope	Depth (m)	2.4 Offshore banks and seamounts	Depth (m)
Veretillum cynomorium (sea pen)			Elba, Gulf of St. Eufemia, Cap de Creus	60–90 70–130 80–120				
Pteroeides spinosum (sea pen)			Giardini Naxos, Cap de Creus	30–160 85–160				
Funiculina quadrangularis (sea pen)			Gulf of St. Eufemia, Cap de Creus	70–130 80–100	Menorca Channel	112–267		
Virgularia mirabilis (sea pen)			Gulf of St. Eufemia, Cap de Creus	70–130 95–120	Menorca Channel	97–140	Malta	250–300
Kophobelemnon stelliferum (sea pen)			Gulf of St. Eufemia	70–130				
Axinella polypoides (sponge)	Cap de Creus	10–70	Gulf of St. Eufemia, Cap de Creus	65–130, 95–130			Vercelli Seamount	70–100
Suberites syringella (sponge)			Gulf of St. Eufemia	90–125	Cap de Creus	85–190		
Haliclona magna (sponge)			Gulf of St. Eufemia	90–120	Menorca Channel	100–297		
Haliclona implexa (sponge)			Gulf of St. Eufemia	80–130				
Poecillastra compressa (sponge)				116–225	Cap de Creus, Menorca Channel, Montecristo Shoals	115–225 94–245 100–200	Marco Bank	200–250
Savalia savaglia (gold coral)	Portofino, Pantelleria	~70 ~80						
Errina aspera (hydrocoral)			Strait of Messina	83–105				

rocky bottoms on the upper part of this bank host dense meadows of the black coral *L. glaberrima*, together with scattered colonies of the gorgonians *A. hirsuta* and *V. flagellum*. Conversely, the gently sloping silted rocky bottom of the Marco Bank is dominated by the gorgonian *C. verticillata* with the associated presence of sparse colonies of *V. flagellum*, *A. hirsuta*, and the black coral *A. dichotoma* (Bo et al. 2014b) (Table 1). The black corals *P. larix* and *L. glaberrima* and a few colonies of the gorgonian *C. verticillata* have also been recently reported on the rocky outcrop on the top of the Palmarola seamount (Ingrassia et al. 2016) (Fig. 2). Finally, in the deep waters of the Malta archipelago (Fig. 2), colonies of the black coral *A. subpinnata* were observed at ~100 m depth, and a community mainly composed

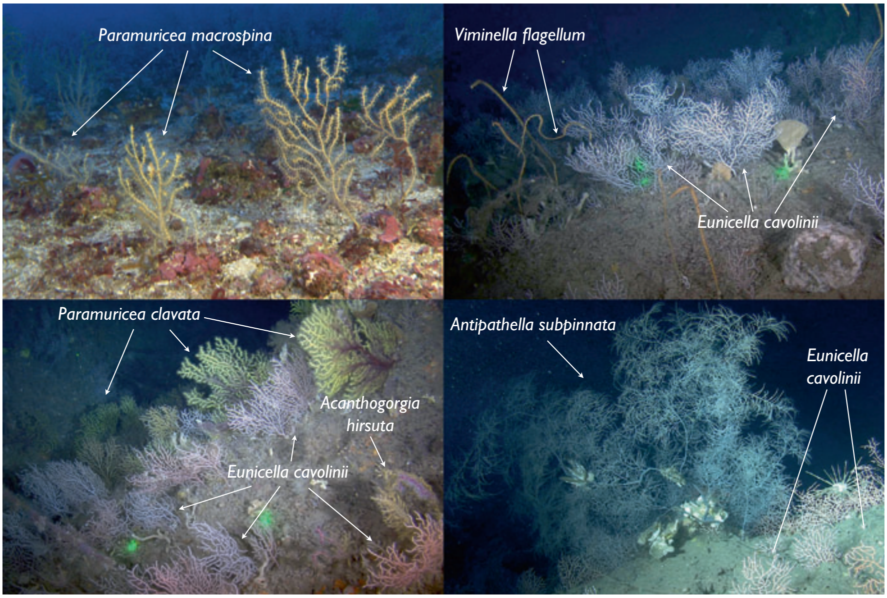

Fig. 4 Menorca Channel. Surveys "Life Indemares" in Balearic Islands supported by European Union, 2010–2012 (70–200 m depth)

of a mixed assemblage of *V. flagellum* and *S. pallida* was observed at 150–240 m depth (Giusti et al. 2012). An extended coral forest constituted by the treelike black coral *L. glaberrima* was observed together with colonies of *A. subpinnata*, *V. flagellum*, and *B. mollis* at 250–400 m depth (Deidun et al. 2015) (Table 1).

3 Case Studies in the Mediterranean Sea

3.1 Cap de Creus

The marine area of Cap de Creus is located in the southernmost part of the Gulf of Lions continental margin (Fig. 2). The position of a terrestrial promontory in proximity of a submarine canyon, together with severe atmospheric conditions and the presence of the Northern Current running close to the shelf edge, generate a complex environmental setting, responsible for the distribution of the benthic fauna along the deep sublittoral bottoms and the narrow continental shelf. The prevailing strong bottom currents, produced by the funneling of shelf water through the submarine canyon toward the deep basin, generate areas of low sediment deposition where coarse-grained deposits with a significant gravel fraction are dominant (Gili et al. 2011). The combination of such strong bottom currents, outcropping rocks, and coarse-grained sediments along with nutrient-rich waters derived from river runoff in the gulf, create suitable conditions for gorgonian-dominated assemblages to fully develop. The distribution of gorgonian species is somehow irregular along the coastline, since the northern side accumulates the highest frequency of occurrence of most species, as well as the highest recorded densities (Rossi et al. 2008; Gori et al. 2011). The white gorgonian *E. singularis* is present throughout the whole deep sublittoral area of the cape, but the patches developing on the northern side are not only more frequent but also hold higher number of colonies, reaching local densities of 30 colonies m^{-2} at 50–70 m depth (Fig. 3 and Table 1) (Gori et al. 2011a). The same pattern is observed for the red gorgonian *P. clavata*, although patches of this species are more scatter and with fewer number of colonies, with maximum densities ~7 colonies m^{-2} below 50 m depth (Fig. 3 and Table 1) (Gori et al. 2011a). The case of the soft-bottom gorgonian *Leptogorgia sarmentosa* is thoroughly different, since most colonies are generally found isolated and profoundly scattered along the entire cape, and very rarely it can be found forming high-density spots (Gori et al. 2011a). *C. rubrum* is present in the entire coastal zone, with significant larger colonies at 50–85 m than in shallower areas at 10–50 m depth (Rossi et al. 2008). Below 80 m depth, *E. cavolinii* replaces the sublittoral gorgonian assemblages, becoming the only gorgonian species that develops well-structured communities on the continental shelf (Fig. 3 and Table 1). Its presence is strongly related to outcropping and suboutcropping rocks, as well as coarse-grained sediments, such as large shells. The distribution of *E. cavolinii* is not exclusively restricted to the northern part of the cape, but well-developed patches reaching densities of 25 colonies m^{-2} have only been found on this side (Gili et al. 2011; Dominguez-Carrió 2017). The presence of this species in the flat habitats of the continental shelf produces an imbricate of tridimensional structures that promote the diversity of other benthic species, being of key importance to sustain the structure of this benthic assemblage, since the diversity of the associated fauna depends largely on the gorgonian abundance (Gili et al. 2011; Dominguez-Carrió 2017).

3.2 Menorca Channel

The Menorca Channel, located between the islands of Mallorca and Menorca (Fig. 2), is formed by a shallow (40–110 m depth) continental shelf mostly covered by extensive maërl beds alternated with detritic sediments and scattered coralligenous banks. In this area, both maërl and coralligenous banks can develop down to ~110 m depth thanks to the high light penetration as a consequence of the extreme clearness of the water (Ballesteros 2006). Shallow maërl beds (40–80 m depth) are mainly covered by dense assemblages of the gorgonian *P. macrospina* (Fig. 4 and Table 1) extending over widespread areas of the channel (Grinyó et al. 2016a). Conversely, in deeper maërl beds (80–120 m depth) gorgonian presence is scarce and mainly replaced by massive sponges like *Haliclona elegans* and *Aplysina cavernicola* (Grinyó et al. 2016a). Shallow coralligenous banks (40–70 m depth) resemble those reported in other coastal areas of the western Mediterranean Sea (Ballesteros 2006), being mostly covered by the coastal gorgonian *P. clavata* and *E. singularis* and erect sponges such as *A. polypoides* (Table 1). Conversely deeper coralligenous banks (70–120 m depth) present a wide abundance and diversity of massive sponges, being *Haliclona pachastrelloides, Hamacantha* sp., and *A. cavernicola* among the most abundant. In these deeper banks the erect part of the animal forest is composed by the gorgonian *E. cavolinii* (Grinyó et al. 2016a) (Table 1). However, it is on the rocky substrates on the continental margins (120–150 m depth) that animal forests reach their higher richness in the Menorca Channel. This environment is dominated by multispecific gorgonian assemblages with high densities (Fig. 4 and Table 1). The black coral *A. subpinnata* is also common in this depth range mostly occurring together with *E. cavolinii* and *P. clavata* (Fig. 4), as it has also been seen in other areas of the Mediterranean (Bo et al. 2009). Isolated colonies of the black corals *A. dichotoma* and *L. glaberrima* are occasionally seen within these gorgonian assemblages. Several soft coral species are associated to these assemblages erect, together with massive or fanlike sponges such us *Haliclona magna*, *P. compressa*, or *Pachastrella monilifera* (Requena and Gili 2014). The well-preserved status of the animal forests in the Menorca Channel is probably related with the low bottom trawling pressure in the area (Requena and Gili 2014; Grinyó et al. 2016a). This area could indeed represent an example of how Mediterranean continental shelves and margins were before the impacts of decades of fishing activities.

3.3 Gulf of St. Eufemia

The Gulf of St. Eufemia, situated along the Calabrian continental shelf (Fig. 2), is a wide plain where the muddy bottoms, enriched by the continental river flows, gently slope down to 130 m depth just a few miles offshore. The area is also spotted by numerous small rocky elevations and sparse boulders emerging from the soft bottom and is lashed by only a slightly turbulent hydrodynamic regime that enhances the silt deposition on the hard grounds (Bo et al. 2012). These rocky shoals in the middle of the continental shelf host rich animal forests dominated by treelike gorgonians and black corals together with an impressive diversity of massive sponges (Fig. 5) (Bo et al. 2012; Bertolino et al. 2015). Due to the high silting conditions and relatively low hydrodynamic regime, bryozoans, ascidians, and encrusting sponges are, on the contrary, present with a relative low abundance. One of the most striking characteristics of the St. Eufemia Gulf deep shoals system is the high diversity of the dominant species on each shoal. The gorgonians *P. macrospina*, *P. clavata*, *E. cavolinii*, and *C. verticillata* dominate the high canopy part of the forests and may reach very large abundance and size (Fig. 5). The small gorgonian *P. macrospina* probably behaves as an opportunistic species, able to colonize various types of either natural or artificial substrates, whereas the black corals *A. subpinnata*, *A. dichotoma*, and *P. larix* are generally present with lower densities and occasionally very large colonies (Fig. 5) (Bo et al. 2012). The animal forests that develop on these shoals behave like small oases of biodiversity characterized by dense aggregations of organisms concentrated in relatively limited rocky habitats, surrounded by otherwise homogeneous soft bottoms (Bo et al. 2012). The susceptibility of these

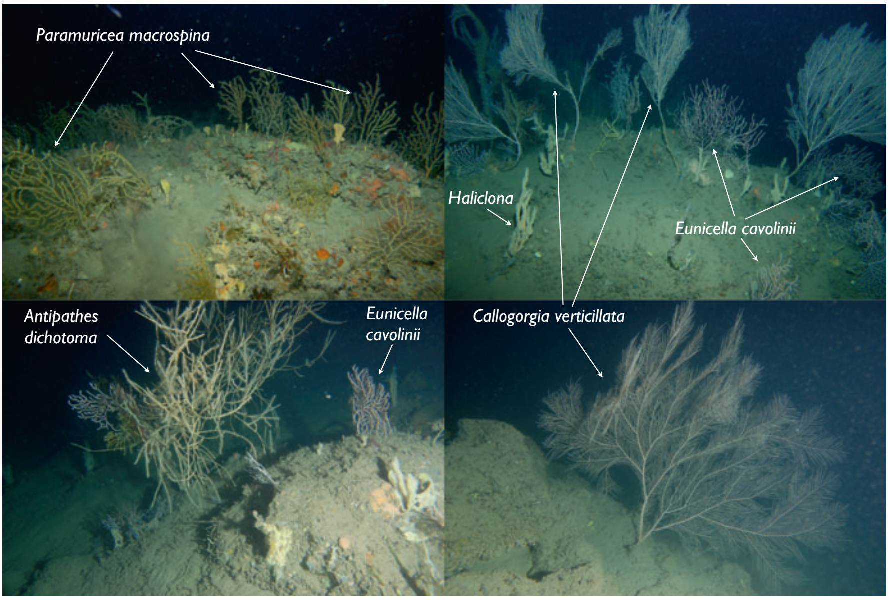

Fig. 5 Gulf of St. Eufemia. Survey "Biodiversity of Calabria" in Calabria supported by Regione Calabria and Ministero dell'Ambiente, 2008 (80–120 m depth)

coral communities to the impacts of local fisheries suggests that the coral oases of the Gulf of St. Eufemia are highly vulnerable habitats.

3.4 Carloforte Shoal

The Carloforte Shoal is located within a complex topographic region of the southwest continental slope of Sardinia (Fig. 2) in which numerous rocky elevations emerge from flat muddy bottoms at about 200 m depth. The shoal is characterized by a series of steep bench terraces continuing into a rocky plateau and surrounded at their base by a belt of mud. This area hosts not only a rich animal forest dominated by the black coral *L. glaberrima* with colonies as large as 2 m high (Fig. 6), but also numerous other black coral and gorgonian species occupying the high canopy layer of the forest and the undergrowth between the larger colonies (Bo et al. 2015). The high longevity of *L. glaberrima* (up to 2,000 years old, Bo et al. 2015) suggests a millennial stability of these deep communities in a heavily exploited basin as the Mediterranean Sea. This is also supported by the presence, on the surrounding enclosed muddy bottoms, of large meadows of the bamboo coral *I. elongata*, a long-lived species subjected to a heavy decline due to trawling fishing (Cartes et al. 2013; Bo et al. 2014c, 2015). The rough topography of the region with rocky elevations sufficiently high to avoid trawling and limiting longline fishing may represent a crucial factor in the persistence of the Carloforte Shoal animal forests

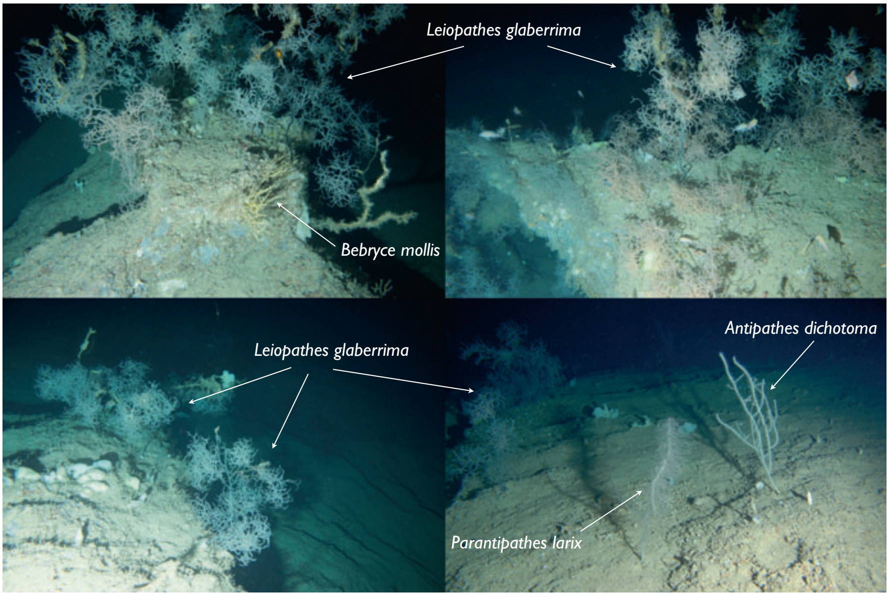

Fig. 6 Carloforte Shoal. Survey “Red Coral” in Sardinia supported by Regione Sardegna, 2013 (200 m depth)

(Bo et al. 2015). As for the animal forests recently observed in the Menorca Channel, those of Carloforte probably represent pristine communities that survived to hundreds of years of fishing impacts.

4 What Do We Know About the Ecology of These Animal Forests?

The dense assemblages of gorgonians and corals recently described in deep sublittoral areas as well as on the continental shelf and shelf edge of the Mediterranean Sea are marine animal forests with high complexity and diversity (Rossi 2013; Bo et al. 2015). From a structural point of view, large treelike cnidarians and sponges act as ecosystem engineers by forming complex three-dimensional frameworks that enhance the spatial heterogeneity in the main environmental factors and represent substrates to colonize or temporary refugees for numerous associated species. From a functional point of view, these species determine a significant flow of matter and energy from the pelagic to the benthic system by capturing plankton and particulate organic matter suspended in the water (Gili and Coma 1998). Finally, the presence of these animal forests increases the organic matter and lipid content in the sediments, thus enhancing meiofaunal biodiversity and biomass (Cerrano et al. 2010, 2015).

4.1 Population Structure

In the coastal area of Cap de Creus, most of the deep *E. singularis* populations at 50–60 m depth present population structures dominated by medium-sized colonies and a high presence of large colonies, which contrast with dominance of small colonies in the shallower populations (Fig. 7) (Linares et al. 2008; Gori et al. 2011b). Similarly, larger *C. rubrum* colonies are present in deep sublittoral bottoms at 60–90 m depth in Cap de Creus (Rossi et al. 2008) as well as at 50–130 m depth in the Tuscany Archipelago (Priori et al. 2013) than in shallow populations. Due to the active harvesting of *C. rubrum*, these differences have been mainly related to a differential fishing pressure in shallow and deep habitat. Conversely, in the case of the non-harvested gorgonians, depth-related differences in their population structure have been linked to the dampened variability in environmental conditions and reduction in hydrodynamic forces with increasing depth in the Mediterranean Sea (Garrabou and Harmelin 2002), since strong water movements cause detachment or toppling of large gorgonian colonies (Weinbauer and Velimirov 1996). Indeed, medium-sized colonies also dominate the deep *P. clavata* populations at 70–130 m depth on the continental shelf of the St. Eufemia Gulf (Bo et al. 2012), as well as *V. flagellum* and especially *S. pallida* at 100–190 m depth on the shelf edge of the Menorca Channel (Grinyó et al. 2016a). Deep *E. cavolinii* populations are mainly dominated by medium-sized colonies in the St. Eufemia Gulf (Bo et al. 2012) as well as in Cap de Creus and the Menorca Channel, whereas in these last two areas the presence of some populations dominated by small colonies (Fig. 7) also highlights active recruitment and high suitability of the habitat for the species (Grinyó et al. 2016a; Dominguez-Carrió 2017). In a similar way, small colonies of *C. verticillata* are much more abundant in the Menorca Channel than in the rocky shoals of the St. Eufemia Gulf (Bo et al. 2012; Grinyó et al. 2016a). The dominance of small colonies in the *P. macrospina* populations on the maërl beds on the continental shelf of the Menorca Channel has been related to the structural instability of this substrate, which prevent the colonies to grow larger, as they can conversely do on the rocky bottom of the shelf edge (Grinyó et al. 2016a). The black corals *L. glaberrima* in the Carloforte Shoal and *P. larix* in the Montecristo shoals also present populations dominated by medium-sized colonies (Bo et al. 2014a, 2015), as well as the bamboo coral *I. elongata* in the pristine population of the Carloforte Shoal (Fig. 7) (Bo et al. 2015).

4.2 Trophic Ecology

Increasing stability of environmental conditions with depth is also reflected in a more constant food supply for deep sublittoral colonies of the gorgonian *E. singularis* at 60 m depth (Gori et al. 2012), as well as for *P. macrospina* and *E. cavolinii* colonies on the continental shelf (Grinyó et al. 2016b; Dominguez-Carrió and Gori unpublished data). Indeed, deep coral and gorgonian populations are not affected by the reduced food availability induced in shallow waters by the water column

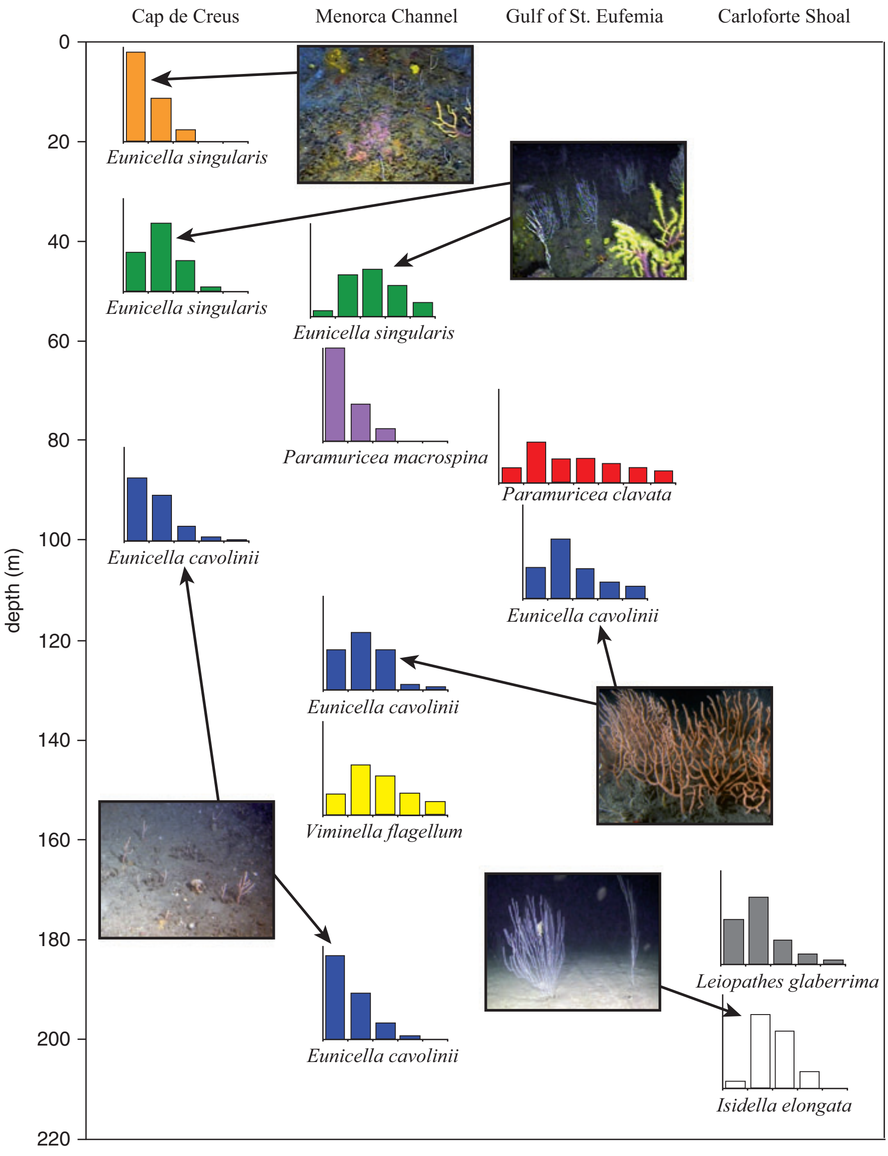

Fig. 7 Size structure of gorgonian and black coral populations in the case study locations; histograms represent the % distribution of colony size in increasing size-classes; photos show specific dominance of small- or medium-sized colonies (data from Gori et al. 2012*;* Bo et al. 2012, 2015; Grinyó et al. 2016a; Dominguez-Carrió unpublished data)

stratification during the Mediterranean summer (Coma et al. 2000). At the same time, stable hydrodynamic conditions dominated by unidirectional currents at deeper depth may sustain a more continuous source of food particles sinking from the

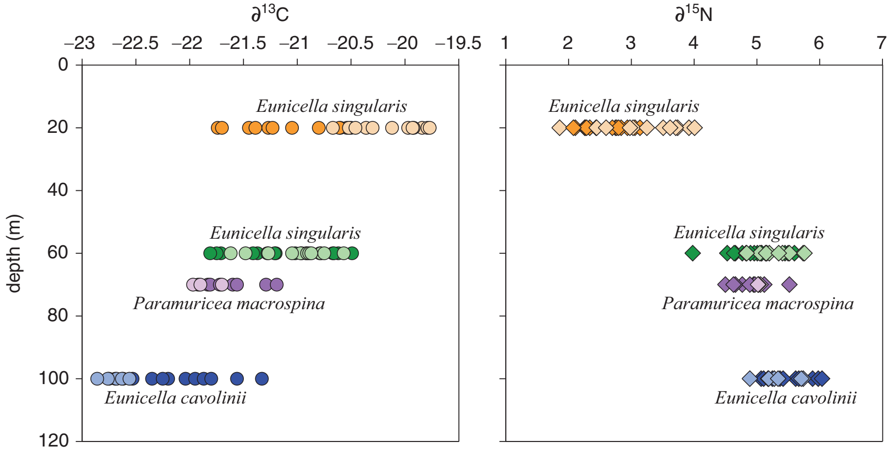

Fig. 8 Stable isotope (13C and 15 N) composition of gorgonian tissue in the Cap de Creus according to depth (data from Gori et al. 2012 and unpublished data; Grinyó et al. 2016b)

surface layer or resuspended from the bottom. Lipid content and C/N composition of tissue are more constant all along the year in *E. singularis* colonies at 60 m depth, whereas a clear seasonality occurs in colonies at 20 m depth (Gori et al. 2012). Similarly, lipid content in gorgonian tissue showed no significant seasonality in *P. macrospina* and *E. cavolinii* on the continental shelf (Grinyó et al. 2016b; Dominguez-Carrió unpublished data). Stable isotope composition shows a summer contribution of symbiotic algae for the C input in the shallow colonies of *E. singularis* (Fig. 8). Even if this contribution is relatively small compared to shallower Mediterranean coral species (Ferrier-Pagès et al. 2011), it clearly differentiates the $\delta^{13}C$ isotopic signature between shallow and deeper sublittoral colonies (Gori et al. 2012). On the continental shelf, the $\delta^{13}C$ signature reflects a similar heterotrophic diet in *P. macrospina* at 70 m depth on the Menorca Channel (Grinyó et al. 2016b) and an even more negative signature in the *E. cavolinii* from the Cap de Creus continental shelf (Fig. 8) (Gori unpublished data). A constant $\delta^{15}N$ isotopic signature, characteristic of suspension feeders feeding on zooplankton and particulate organic matter, is basically shared by the deep colonies of the three gorgonian species (Grinyó et al. 2016b; Gori et al. 2012 and unpublished data), contrasting with the uptake of inorganic N mediated by the symbiotic algae in the shallow *E. singularis* colonies (Fig. 8).

4.3 Sexual Reproduction

Deep Mediterranean gorgonian species studied so far showed a single reproductive season during summer, similarly to shallow species. The deep sublittoral colonies of *E. singularis* at 60 m depth in Cap de Creus were found to reproduce almost simultaneously with the shallower ones at 20 m depth. However, the release of larvae from the female colonies was more prolonged in the shallow (June and July) than in the deep colonies (June) (Gori et al. 2012). Deeper on the continental shelf at 100 m depth, *E. cavolinii* was also observed to release larvae in July in Cap de Creus (Dominguez-Carrió unpublished data), whereas *P. macrospina* spawn gametes between August and September at 70 m depth in the Menorca Channel (Grinyó et al. 2016b). Total volume of oocytes produced per polyp in *E. singularis* at 60 m depth was slightly minor than at 20 m depth (Gori et al. 2012). Conversely, total volume of oocytes significantly increased in *P. macrospina* and *E. cavolinii* on the continental shelf. This increase was due to the production of a larger number of oocytes in *P. macrospina* (Grinyó et al. 2016b), whereas few but very large oocytes were produced by *E. cavolinii* (Dominguez-Carrió unpublished data).

4.4 Associated Fauna

The spatial heterogeneity generated by the complex three-dimensional framework formed by gorgonians, black corals, and sponges provides suitable habitat for hundreds of associated species. The main environmental features, such as current flow, food availability, and sediment resuspension, vary widely within these complex structures, and this heterogeneity increases the abundance and functional diversity of both the nektonic and benthonic associated fauna.

Species associated with living portions of corals are relatively uncommon due to the fact that corals have nematocysts or produce great quantities of mucus (in the case of black corals) that discourages potential stable associations (Bo et al. 2015). Among the most interesting associations, those with hydroids are especially remarkable, for instance, *Sertularella crassicaulis* on *E. cavolinii* or the recently described *Ectopleura* sp., a solitary hydroid living in apparently neutral association with numerous deep gorgonian species as well as with the black coral *A. subpinnata* (Bo et al. 2011c). This hydroid settles on the branches of the coral and allows the host’s coenenchyme to envelope its perisarc resulting perfectly mimicked within the coral. Close associations are reported also for ophiuroids and crabs (as *Anamathia rissoana*) living on the ramifications of gorgonians and black corals (Bo et al. 2014a, 2015). Specialized predators such as ovulid gastropods are often found in almost exclusive association with the corals they prey, such as *Neosimnia* spp. on *E. cavolinii* and *C. rubrum* or the recently described association of *Aperiovula juanjosensii* with several deep gorgonian species (Bo et al. 2012). Similarly, the stylasterid coral *E. aspera* shows a peculiar association with the gastropod *Pedicularia sicula* (Salvati et al. 2010). The carbonate, gorgonin, and chitin skeletons of corals and gorgonians represent a suitable substrate for several organisms, in particular hydroids, sponges, bryozoans, anemones, zoanthids, soft corals, scleractinians, stalked barnacles, bivalves, ascidians, and polychaetes living on the dead portions of the colonies (Bo et al. 2009, 2012, 2015; Deidun et al. 2015). Occasionally, ophiuroids, crinoids, gastropods, bivalves, and small anthozoans also colonize the naked branchlets (Bo et al. 2015). Many fish species find a temporary refuge among coral branches of the deep Mediterranean animal forests, being the most common *Anthias anthias*, *Callanthias ruber*, *Macroramphosus scolopax*, *Zeus faber*, *Lappanella fasciata*, *Helicolenus dactylopterus*, *Trachurus* sp., and *Benthocometes robustus*; the latter being one of the most characteristic fish species in black coral forests. Also the catshark *Scyliorhinus canicula* is commonly observed moving around in both shallow and deepwater gorgonian and coral assemblages (Bo et al. 2015). The coral assemblages developing on hard bottoms typically show a strong relationship with the presence of fish (Mytilineou et al. 2014). Conversely, the relationship among the presence of fish and the occurrence of soft bottom coral assemblages seems to be more occasional (Cartes et al. 2013). The coral treelike canopy represents an optimal substrate to lay eggs for catshark and ray species. This can occur only occasionally or, as in the case of the Carloforte Shoal, be widely extended to the entire coral assemblage such that the site may turn into a nursery area. It therefore becomes evident the fragile but crucial relationship among the persistence of the coral assemblages and the survivorship of local populations of catsharks (Bo et al. 2015).

5 Treats

5.1 Fishing Impact

The gorgonians and corals forming the Mediterranean animal forests from deep coastal areas, continental shelf, shelf edge, and slope are among the most abundant and frequent species in fishing bycatch (Cartes et al. 2013; Mytilineou et al. 2014; Deidun et al. 2015). This is not surprising considering that many fish of commercial interest are often associated to these animal forests, which are consequently largely exploited by professional and recreational fishermen. All fishing activities operated with demersal gears impact the megabenthic communities and particularly the large treelike corals and sponges which are particularly vulnerable due to their shape and size, as they remain easily entangled in nets and longlines (Fig. 9). The catchability of a coral depends also on the type of gear, the nature of the coral skeleton, and its mechanical properties as well as on its type of aggregation on the sea bottom (Mytilineou et al. 2014; Bo et al. 2014c). Fishing impacts can directly remove the organisms (especially bottom trawling), cause partial damage (especially trammel net and longline fishing) (Fig. 9), as well as induce indirect consequence, such as epibionts overgrowing or chocking and burial caused by the resuspension of nearby sediments (due to bottom trawling) (Bo et al. 2014c). These impacts can have far-reaching and long-lasting effects for deep-sea ecosystems dominated by longevous, slow-growing species with low recovery ability due to the natural fragmentation of the populations and the limited larval dispersion and population connectivity (Bo et al. 2015).

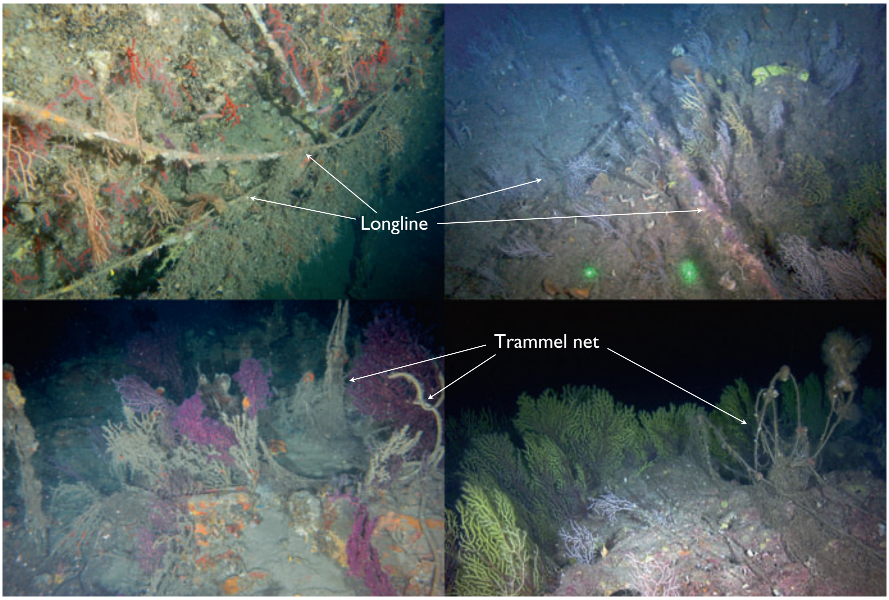

Fig. 9 Fishing impacts on gorgonian assemblages; (*up left*) longlines on *Corallium rubrum* and *Eunicella cavolini* (survey "Red Coral" financed by Ministero dell'Ambiente, 2010–2012, Ischia 80 m depth) and (*up right*) *Paramuricea clavata* and *E. cavolinii* (surveys "Life Indemares" financed by European Union, 2010–2012, Cap de Formentor 120 m depth); (*down left*) trammel net on *Paramuricea clavata* (survey "Marine Strategy" financed by ARPA Liguria, 2015, Vado Ligure 60 m depth) and (*down right*) *Paramuricea clavata* and *E. cavolinii* (surveys "Life Indemares" financed by European Union, 2010–2012, Cap de Formentor 120 m depth)

5.2 Deep Mass Mortalities

Mediterranean mass mortalities of shallow gorgonians and sponges have severely increased in frequency and intensity over the past 30–40 years (Garrabou et al. 2009). These episodes are considered related to summer thermal anomalies in shallow waters (from the surface to 40–50 m depth) associated to global warming, sometimes enhancing bacterial infections. Conversely, very few data are available for deep gorgonian, coral, and sponge populations. Rivoire (1991) described a gorgonian and red coral mortality occurred off the Provence coastline at 80–160 m depth, tentatively attributed to polluted waters driven by dominant currents. Recently, an extensive mass mortality of *C. rubrum* at 90 m depth in an area not subjected to strong urban pollution was described in the Gulf of Salerno (Bavestrello et al. 2014). The occurrence of entire dead colonies without evident ruptures of branches excludes mechanical injuries, such as those produced by fishing activities. Neither can the mortality simply be attributed to pollution or thermal anomalies related to global changes nor due to the offshore location and depth of the site. One of the suggested hypotheses is that costal debris flows could produce gravity flows and submarine landslides with a consequent unusual drop of the summer thermocline. However, an alternative hypothesis takes in consideration sudden warmwater emissions, in an area characterized by important volcanic activities. Similar events are probably at the origin of the huge subfossil Sciacca red coral banks discovered in 1875 in the Sicily Channel. The typical orange color of the Sciacca coral would indeed be a consequence of prolonged exposure of the buried skeletons to hydrothermal emissions. Mass mortalities of the red coral populations probably occurred periodically for thousands of years giving rise to the accumulation of skeletal structures on the sea bottoms (Bavestrello et al. 2014).

5.3 Other Sources of Impact

Beside fishing activities and natural catastrophic events, it is possible to identify other sources of impact, mainly man driven, for the animal forests thriving on deep coastal areas and the continental shelf. As already suggested, there are some evidences that support the occurrence of deep mass mortalities potentially related to pollution (Rivoire 1991). No specific studies have been carried out on the effects of sewage discharges and river outflows, whether it is plausible that they may act on the most coastal assemblages. Moreover, seafloor drilling activities for oil exploration or mining are greatly threatening the integrity of several deep benthic communities (Aguilar 2004).

6 Future Research and Actions

Coral aggregations, internationally recognized as “coral gardens,” are considered as vulnerable marine ecosystems (VMEs), a term coined by UN which identifies species, communities, or habitats vulnerable to fishing activity. Based on the video footage gathered by means of ROV studies performed in the recent years in the Mediterranean Sea, there is indeed a growing concern that completely pristine deep animal forests are nowadays an exception due to fortuitous environmental constraints or local low industrial fishing efforts and that many of them are becoming extinct in the areas strongly exploited by fishermen (Bo et al. 2014c, 2015; Grinyó et al. 2016a). Studies are providing evidence that these deep animal forests are probably a small portion of the original natural ones (Bo et al. 2014c). The information supplied by recent studies focused on these assemblages has conducted to the inclusion of several gorgonian and coral species in the Mediterranean IUCN Red List and the Barcelona Convention list. Further efforts should be targeted on the identification of the occurrence and distribution of deep animal forests, and conservation and management measures should be adopted to preserve these assemblages, including offshore areas. An ecosystem-based fishery management of deep-sea ecosystems based on fishing restrictions, as recently carried out in the Gulf of Lions (Fabri et al. 2014), is fundamental for the conservation of deep animal forests. Self-regulations of the fishing grounds, as operated in the Menorca Channel by a small artisanal fishing fleet (Requena and Gili 2014), may also be useful tools to preserve these ecosystems. This approach must take into account the complex sociocultural background of the recreational and professional Mediterranean fishermen and the economical and physical constraints in monitoring and controlling offshore areas often localized in international waters (Bo et al. 2014c).

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References

Aguiliar R. The corals of the Mediterranean. Oceana, Fundacion Biodiversidad; 2004.

Ambroso S, Gori A, Dominguez-Carrió C, Gili JM, Berganzo E, Teixidó N, Greenacre M, Rossi S. Spatial distribution patterns of the soft corals *Alcyonium acaule* and *Alcyonium palmatum* in coastal bottoms (Cap de Creus, northwestern Mediterranean Sea). Mar Biol. 2014;160:3059–70.

Angiolillo M, Bo M, Bavestrello G, Giusti M, Salvati E, Canese S. Record of *Ellisella paraplexauroides* (Anthozoa: Alcyonacea: Ellisellidae) in Italian waters (Mediterranean Sea). Mar Biodivers Rec. 2012;5:e4.

Angiolillo M, di Lorenzo B, Farcomeni A, Bo M, Bavestrello G, Santangelo G, Cau A, Mastascusa V, Cau A, Sacco F, Canese S. Distribution and assessment of marine debris in the deep Tyrrhenian Sea (NW Mediterranean Sea, Italy). Mar Pollut Bul. 2015;92:149–59.

Ballesteros E. Mediterranean coralligenous assemblages: a synthesis of present knowledge. Oceanogr Mar Biol Annu Rev. 2006;44:123–95.

Bavestrello G, Bo M, Canese S, Sandulli R, Cattaneo-Vietti R. The red coral populations of the gulfs of Naples and Salerno: human impact and deep mass mortalities. Ital J Zool. 2014;81:552–63.

Bertolino M, Bo M, Canese S, Bavestrello G, Pansini M. Deep sponge communities of the Gulf of St. Eufemia (Calabria, southern Tyrrhenian Sea), with description of two new species. J Mar Biol Assoc UK. 2015;95:1371–87.

Bo M, Tazioli S, Spanò N, Bavestrello G. *Antipathella subpinnata* (Antipatharia, Myriopathidae) in Italian seas. Ital J Zool. 2008;75:185–95.

Bo M, Bavestrello G, Canese S, Giusti M, Salvati E, Angiolillo M, Greco S. Characteristics of a black coral meadow in the twilight zone of the central Mediterranean Sea. Mar Ecol Prog Ser. 2009;397:53–61.

Bo M, Bertolino M, Borghini M, Castellano M, Harriague C, Di Camillo CG, Gasparini GP, Misic C, Povero P, Schroeder K, Bavestrello G. Characteristics of the mesophotic megabenthic assemblage of the Vercelli Seamount (North Tyrrhenian Sea). PLoS One. 2011a;6:e16357.

Bo M, Bavestrello G, Canese S, Giusti M, Angiolillo M, Cerrano C, Salvati E, Greco S. Coral assemblages off the Calabrian Coast (South Italy) with new observations on living colonies of *Antipathes dichotoma*. Ital J Zool. 2011b;78:231–42.

Bo M, Di Camillo CG, Puce S, Canese S, Giusti M, Angiolillo M, Bavestrello G. A tubulariid hydroid associated with anthozoan corals in the Mediterranean Sea. Ital J Zool. 2011c;78:487–96.

Bo M, Canese S, Spaggiari C, Pusceddu A, Bertolino M, Angiolillo M, Giusti M, Loreto MF, Salvati E, Greco S, Bavestrello G. Deep coral oases in the South Tyrrhenian Sea. PLoS One. 2012;7:e49870.

Bo M, Canese S, Bavestrello G. Discovering Mediterranean black coral forests: *Parantipathes larix* (Anthozoa: Hexacorallia) in the Tuscan Archipelago. Ital J Zool. 2014a;81:112–25.

Bo M, Cerrano C, Canese S, Salvati E, Angiolillo M, Santangelo G, Bavestrello G. The coral assemblages of an off-shore deep Mediterranean rocky bank (NW Sicily, Italy). Mar Ecol. 2014b;35:332–42.

Bo M, Bava S, Canese S, Angiolillo M, Cattaneo-Vietti R, Bavestrello G. Fishing impact on deep Mediterranean rocky habitats as revealed by ROV investigation. Biol Conserv. 2014c;171:167–76.

Bo M, Bavestrello G, Angiolillo A, Calcagnile L, Canese S, Cannas R, Al C, D'Elia M, D'Oriano F, Follesa MC, Quarta G, Cau A. Persistence of pristine deep-sea coral gardens in the Mediterranean Sea (SW Sardinia). PLoS One. 2015;10:e0119393.

Carpine C, Grasshoff M. Les gorgonaires de la Méditerranée. Bull Inst Océanogr Monaco. 1975;71:1–140.

Cartes JE, Lo Iacono C, Mamouridis V, López-Pérez C, Rodríguez P. Geomorphological, trophic and human influences on the bamboo coral *Isidella elongata* assemblages in the deep Mediterranean: to what extent does *Isidella* form habitat for fish and invertebrates? Deep Sea Res I. 2013;76:52–65.

Cau A, Follesa MC, Moccia D, Alvito A, Bo M, Angiolillo M, Canese S, Paliaga EM, Orrù PE, Sacco F, Cannas R. Deepwater corals biodiversity along *roche du large* ecosystems with different habitat complexity along the south Sardinia continental margin (CW Mediterranean Sea). Mar Biol. 2015;162:1865–78.

Cerrano C, Danovaro R, Gambi C, Pusceddu A, Riva A, Schiaparelli S. Gold coral (*Savalia savaglia*) and gorgonian forests enhance benthic biodiversity and ecosystem functioning in the mesophotic zone. Biodivers Conserv. 2010;19:153–67.

Cerrano C, Bianchelli S, Di Camillo CG, Torsani F, Pusceddu A. Do colonies of *Lytocarpia myriophyllum*, L. 1758 (Cnidaria, Hydrozoa) affect the biochemical composition and the meiofaunal diversity of surrounding sediments? Chem Ecol. 2015;31:1–21.

Coma R, Ribes M, Gili JM, Zabala M. Seasonality in coastal benthic ecosystems. Tree. 2000;15:448–53.

Coppari M, Gori A, Viladrich N, Saponari L, Canepa A, Grinyó J, Olariaga A, Rossi S. The role of Mediterranean sponges in benthic–pelagic coupling processes: *Aplysina aerophoba* and *Axinella polypoides* case studies. J Exp Mar Biol Ecol. 2016;477:57–68.

Deidun A, Tsounis G, Balzan F, Micallef A. Records of black coral (Antipatharia) and red coral (*Corallium rubrum*) fishing activities in the Maltese Islands. Mar Biodivers Rec. 2010;3:e90.

Deidun A, Andaloro F, Bavestrello G, Canese S, Consoli P, Micallef A, Romeo T, Bo M. First characterization of a *Leiopathes glaberrima* (Cnidaria: Anthozoa: Antipatharia) forest in Maltese exploited fishing grounds. Ital J Zool. 2015;82:271–80.

Di Camillo CG, Boero F, Gravili C, Previati M, Torsani F, Cerrano C. Distribution, ecology and morphology of *Lytocarpia myriophyllum* (Cnidaria: Hydrozoa), a Mediterranean Sea habitat former to protect. Biodivers Conserv. 2013;22:773–87.

Dominguez-Carrió C. ROV-based ecological study and management proposals for the offshore marine protected area of Cap de Creus (NW Mediterranean). PhD thesis, Universitat de Barcelona; 2017.

Fabri MC, Pedel L, Beuck L, Galgani F, Hebbeln D, Freiwald A. Megafauna of vulnerable marine ecosystems in French Mediterranean submarine canyons: spatial distribution and anthropogenic impacts. Deep Sea Res II. 2014;104:184–207.

Ferrier-Pagès C, Peirano A, Abbate M, Cocito S, Negri A, Rottier C, Riera P, Rodolfo-Metalpa R, Reynaud S. Summer autotrophy and winter heterotrophy in the temperate symbiotic coral *Cladocora caespitosa*. Limnol Oceanogr. 2011;56:1429–38.

Garrabou J, Harmelin JG. A 20-year study on life-history traits of a harvested long-lived temperate coral in the NW Mediterranean: insights into conservation and management needs. J Anim Ecol. 2002;71:966–78.

Garrabou J, Coma R, Chevaldonné P, Cigliano M, Diaz D, Harmelin JG, Gambi MC, Kersting DK, Lejeune C, Linares C, Marschal C, Pe´rez T, Ribes M, Romano JC, Teixido N, Serrano E, Torrents O, Zabala M, Zuberer F, Cerrano CA. Mass mortality in NW Mediterranean rocky benthic communities: effects of the 2003 heat wave. Glob Change Biol. 2009;15:1090–103.

Giacobbe S, Laria G, Spanò N. Hard bottom assemblages in the strait of Messina: distribution of *Errina aspera* L.(Hydrozoa: Stylasteridae). Rapp Comm Int Mer Med. 2007;38:485.

Gili JM, Coma R. Benthic suspension feeders: their paramount role in littoral marine food webs. Tree. 1998;13:316–21.

Gili JM, Murillo J, Ros J. The distribution pattern of benthic cnidarians in the western Mediterranean. Sci. Mar. 1989;53:19–35.

Gili JM, Madurell T, Requena S, Orejas C, Gori A, Purroy A, Domínguez C, Lo Iacono C, Isla E, Lozoya JP, Carboneras C, Grinyó J, Sardá R. Caracterización física y ecológica del área marina del Cap de Creus. Informe final área LIFE + INDEMARES (LIFE07/NAT/E/000732). Instituto de Ciencias del Mar/CSIC (Barcelona). Fundación Biodiversidad; 2011.

Giusti M, Bo M, Bavestrello G, Angiolillo M, Salvati E, Canese S. Record of *Viminella flagellum* (Alcyonacea: Ellisellidae) in Italian waters (Mediterranean Sea). Mar Biodivers Rec. 2012;5:e34.

Gori A, Rossi S, Berganzo E, Pretus JL, Dale MR, Gili JM. Spatial distribution patterns of the gorgonians *Eunicella singularis*, *Paramuricea clavata*, and *Leptogorgia sarmentosa* (Cape of Creus, Northwestern Mediterranean Sea). Mar Biol 2011a;158:143–158.

Gori A, Rossi S, Linares C, Berganzo E, Orejas C, Dale MRT, Gili JM. Size and spatial structure in deep versus shallow populations of the Mediterranean gorgonian *Eunicella singularis* (Cap de Creus, northwestern Mediterranean Sea). Mar Biol. 2011b;158:1721–1732.

Gori A, Viladrich N, Gili JM, Kotta M, Cucio C, Magni L, Bramanti L, Rossi S. Reproductive cycle and trophic ecology in deep versus shallow populations of the Mediterranean gorgonian *Eunicella singularis* (Cap de Creus, northwestern Mediterranean Sea). Coral Reefs. 2012;31:823–37.

Gori A, Orejas C, Madurell T, Bramanti L, Martins M, Quintanilla E, Marti-Puig P, Lo Iacono C, Puig P, Requena S, Greenacre M, Gili JM. Bathymetrical distribution and size structure of cold-water coral populations in the Cap de Creus and Lacaze-Duthiers canyons (northwestern Mediterranean). Biogeosciences. 2013;10:2049–2060.

Grinyó J, Gori A, Ambroso S, Purroy A, Calatayud C, Dominguez-Carrió C, Coppari M, Lo Iacono C, López-González P, Gili JM. Distribution and population size structure of unexpectedly well-preserved deep Mediterranean gorgonian assemblages (Menorca Channel, western Mediterranean Sea). Prog Oceanogr. 2016a;145:42–56.

Grinyó J, Viladrich N, Gori A, Díaz D, Mayol S, Muñoz A, Salazar J, Castillo R, Rossi S, Gili JM. Reproduction and energy storage in a gorgonian coral on the continental shelf (Menorca Channel, western Mediterranean Sea). Coral Reef. 2016b; submitted.

Ingrassia M, Macelloni L, Bosman A, Chiocci FL, Cerrano C, Martorelli E. Black coral (Anthozoa, Antipatharia) forest near the western Pontine Islands (Tyrrhenian Sea). Mar Biodiv. 2016;46:285–90.

Laban A, Pérès JM, Picard J. La photographie sous-manne profonde et son exploitation scientifique. Bull Inst océanogr Monaco. 1963;60:1–32.

Linares C, Coma R, Garrabou J, Díaz D, Zabala M. Size distribution, density and disturbance in two Mediterranean gorgonians: *Paramuricea clavata* and *Eunciella singularis*. J Appl Ecol. 2008;45:688–99.

Martin J. Rôle des bathyscaphes dans l'exploration scientifique des océans. L'Astron. 1960;74:349–65.

Mytilineou C, Smith CJ, Anastasopoulou A, Papadopoulou KN, Christidis G, Bekas P, Kavadas S, Dokos J. New cold-water coral occurrences in the Eastern Ionian Sea: results from experimental long line fishing. Deep Sea Res II. 2014;99:146–57.

Orejas C, Gori A, Lo Iacono C, Puig P, Gili JM. Cold-water corals in the Cap de Creus canyon, northwestern Mediterranean: spatial distribution, density and anthropogenic impact. Marine Ecology Progress Series. 2009;397:37–51.

Pérès JM, Picard J. Nouveau manuel de bionomie benthique de la mer. Rec Trav Sta mar Endoume. 1964;47:5–137.

Porporato EM, Mangano MC, De Domenico F, Giacobbe S, Spanò N. First observation of *Pteroeides spinosum* (Anthozoa: Octocorallia) fields in a Sicilian coastal zone (Central Mediterranean Sea). Mar Biodivers. 2014;44:589–92.

Priori C, Mastascusa V, Erra F, Angiolillo M, Canese S, Santangelo G. Demography of deep-dwelling red coral populations: age and reproductive structure of a highly valued marine species. Estuar Coast Shelf Sci. 2013;118:43–9.

Requena S, Gili JM. Caracterización ecológica del área marina del Canal de Menorca: zonas profundas y semiprofundas (100–400 m). Informe final área LIFE+ INDEMARES (LIFE07/NAT/E/000732). Instituto de Ciencias del Mar, Consejo Superior de Investigaciones Científicas (Barcelona). Fundación Biodiversidad; 2014.

Reyss D, Soyer J. Étude de deux vallées sous-marines de la mer Catalane: le rech du Cap et le rech Lacaze-Duthiers en «soucoupe plongeante» (Note preliminaire). Rapp Comm int Mer Médit. 1965;18:75–81.

Rivoire G. Mortalité de corail et de gorgones en profondeur au large des côtes provençales. In: Boudouresque CF, Avon M, Gravez V, editors. Les espèces marines à protéger en Méditerranée. Marseille: GIS Posidonies; 1991. p. 53–9.

Rossi S. The destruction of the ‘animal forests’ in the oceans: towards an over-simplification of the benthic ecosystems. Ocean Coast Manage. 2013;84:77–85.

Rossi S, Tsounis G, Orejas C, Padrón T, Gili JM, Bramanti L, Teixidó N, Gutt J. Survey of deep-dwelling red coral (*Corallium rubrum*) populations at Cap de Creus (NW Mediterranean). Mar Biol. 2008;154:533–45.

Salomidi M, Smith C, Katsanevakis S, Panayotidis P, Papathanassiou V. Some observations on the structure and distribution of gorgonian assemblages in the eastern Mediterranean Sea. Proc 1st Med Symp Conserv Coral Bio. 2009;1:242–5.

Salvati E, Angiolillo M, Bo M, Bavestrello G, Giusti M, Cardinali A, Puce S, Spaggiari C, Greco S, Canese S. The population of *Errina aspera* (Hydrozoa, Stylasteridae) of the Messina Strait (Mediterranean Sea). J Mar Biol Assoc UK. 2010;90:1331–6.

Sink KJ, Boshoff W, Samaai T, Timm PG, Kerwath SE. Observations of the habitats and biodiversity of the submarine canyons at Sodwana Bay. S Afr J Sci. 2006;102:466–74.

Vaissière R, Carpine C. Compte-rendu de plongées en soucoupe plongeante SP 300 (Région A1: Cap Camarat-St Tropez) – Fascicule 4. Bull Inst océanogr Monaco. 1964;63:1–32.

Weinbauer M, Velimirov B. Population dynamics and overgrowth of the sea fan *Eunicella cavolinii* (Coelenterata: Octocorallia). Estuar Cstl Shelf Sci. 1996;42:583–95.