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Review

Black Coral Distribution in the Italian Seas: A Review

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Abstract: Antipatharian corals are important structural and complex members of benthic communities inhabiting the Italian seafloor. In this study, the distribution of black corals in Italy is reported and mapped for the first time. This review has permitted the identification of occurrences of such vulnerable marine ecosystems along the Italian coasts in a bathymetric range of 42 m to 790 m. Black corals appear to be most conspicuous and widely distributed in the mesophotic zone (from around 60 to 300 m depth), with a major occurrence on the rocky bottom and shoals. This review also highlights that these communities suffer direct damage from anthropogenic impacts (fishing activity and lost garbage). Finally, this study provides evidence that the reported Italian submarine sites associated with the occurrence of black corals probably represent only a small portion of their real distribution. This finding urges the need to increase monitoring efforts to support the protection and the conservation of these pristine species assemblages.

Keywords: Antipatharia; vulnerable marine ecosystems; anthropogenic impact

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1. Introduction

Black corals (Cnidaria: Anthozoa: Hexacorallia: Antipatharia) are characterized by arborescent vertical or monopodial growth forming three-dimensional habitats supporting high levels of biodiversity [1,2]. Antipatharian corals have been considered for a long time to be among the rarest and sporadic coral species in the Mediterranean Sea [3]. To date, it is well known that these corals are able to form dense aggregations forming pristine underwater forests [4].

Within the Italian seas, five species of black corals have been reported: *Antipathes dichotoma* Pallas, 1766 and *Antipathes fragilis*, Gravier, 1918 (both Antipathidae), *Leiopathes glaberrima* (Esper, 1972) (Leiopathidae), *Antipathella subpinnata* (Ellis & Solander, 1786) (Myriopathidae), and *Parantipathes larix* (Esper, 1788) (Schizopathidae). Actually, the latter was lost and its taxonomic position is highly dubious [5]. Such corals are mainly found in a water depth of 60 m to 300 m [4,6], forming characteristic ecological niches hosting rich associated fauna and attracting numerous species of commercial interest [1,7].

Because of their rarity, black corals low growth rates, and low recovery ability, are considered extremely sensitive and listed as indicator species of vulnerable marine ecosystems (VMEs). For this reason, they are mentioned in several international agreements concerning marine ecosystem conservation (CITES Appendix II [available at http://www.cites.org]; European Community 1999), in Annex III of the Berna Convention, in Annex II of the Barcelona Convention for the Mediterranean species, and are also categorized as "threatened" by the International Union for Conservation of Nature (IUCN) Red List of Mediterranean Anthozoa [8] (with the millennial life span *L. glaberrima* being the only one listed as "endangered"). The main anthropogenic impact affecting these corals is represented by fishing as artisanal and recreational activities and bottom trawling, which may cause the resuspension of fine sediments [4,9,10]. Rare activities related to the commercial fisheries of precious corals for the jewelry industry is also reported [11].

Review studies on deep coral assemblages in the Mediterranean Sea have mainly been limited to scleractinian corals (i.e., *Lophelia* and *Madrepora* [12,13]), while few studies were exclusively focused on the distribution of black corals in the Italian seas [4,5,14–17]. The Italian seas have an average depth of about 1500 m, and a maximum depth of about 5000 m. The main Italian seas are the Tyrrhenian, Adriatic, and Ionian, and the other seas are represented by the Ligurian and Corsica seas, and the Otranto, Messina, and Sicily straits. The seawater temperatures range from 12 °C to 13 °C during the cold season, and from 26 °C to 28 °C in the warm season. Temperatures at the seafloor are constant and range from 12 °C to 13 °C [18]. During the last decades, the temperatures of the Italian seas have significantly increased [19], which resulted in dramatic changes in biodiversity composition [18]. To date, 29 Italian Marine Protected Areas (MPAs) have been established, but this number strongly needs to be updated [20].

The aim of this study is to present a review of the knowledge on the occurrence of black corals in the Italian seas, providing the first comprehensive distribution map of these species. The distribution of black corals may be considered the first step towards defining a more complete overview regarding the present knowledge on these vulnerable species. This study also highlights the need for the conservation programs protecting black corals in the Italian seas.

2. Distribution Dataset and Methods

Table 1 shows dataset of black coral distribution in the Italian Seas. This dataset was created using all the available scientific literature and reports, starting from 1973 until today. For each site, when available, the following information was reported: region, ID (number code referred to the code reported in Figure 1), sites, sea, coral species, minimum and maximum depth, setting, substrate, anthropogenic impact, reference. The type of setting is based on the classification used by Gori et al. [6], whereas the substrate types were referred to those reported in the related scientific articles. The categories related to anthropogenic impact are represented by fishing activity (trawl and ghost nets, longlines, lines, ropes, other fishing gear) and lost garbage (e.g., plastic and metal objects).

All the sites reported in Table 1 were used to create the first distribution map of black corals in the Italian seas (Figure 1).

In the reported studies remotely operated vehicles (ROVs) and multibeam echosounders (MBES) were used for the identification of black coral specimens and the description of the geomorphological characteristics of the substrate [4,5,14–17].

Table 1. Dataset of the Italian submarine sites associated with black corals reported in the available scientific literature. Codes used for the black corals: AS, *Antipathella subpinnata*; AD, *Antipathes dichotoma*; AF, *Antipathes fragilis*; LG, *Leiopathes glaberrima*; PL, *Parantipathes larix*. Code nd means "no data".

Region	ID	Site	Sea	Coral	Min Depth	Max Depth	Setting	Substrate	Anthropogenic Impact	Reference
Ligurian	1	Banco di S. Lucia	SE Ligurian Sea	AS, AD, LG, PL	140	210	Offshore banks and seamounts	Deep rocky banks	Fishing activity	[4,21]
Sicily	2	Mantice Shoal	Western Ligurian Sea	AS	70	150	Shelf edge and upper slope	Deep rocky banks	Fishing activity	[4]
	3	Portofino Secca dell'Isuela	Ligurian Sea	AS	56	60	Shelf	Shoal	nd	[17,22,23]
	4	Bordighera	West Ligurian Sea	AS	63	63	Shelf	nd	nd	[22]
	5	Wreck Ravenna	Ligurian Sea	AS	75	90	Shelf	Rocky bottom	nd	[20]

Table 1. *Cont.*

	6	Punta Faro	Ligurian Sea	AS	63	77	Shelf	Shoal	nd	[23]
	37	Marco Bank	Western Sicily	LG	240	260	Offshore banks and seamounts	Deep rocky banks	Fishing activity	[24]
	38	Graham Shoal	Strait of Sicily	LG	95	150	Offshore banks and seamounts	Shoal	nd	[25]
	39	Favignana and Talbot Shoal	Strait of Sicily	LG	100	100	Offshore banks and seamounts	Shoal	nd	[26]
	40	Filicudi Aeolian islands	Tyrrhenian Sea	AD	75	300	Shelf edge and upper slope	Rocks encrusted by coralline algae	nd	[27,28]
	41	Filicudi Aeolian islands	Tyrrhenian Sea	LG	300	300	Deep areas	Rocky bottom	nd	[27,28]
	42	Cape San Vito Sicily	Tyrrhenian Sea	LG	275	286	Deep areas	nd	nd	[26,27]
	43	Messina Strait	Secche di Favazzina	AS	55	70		Rocky bottom	nd	[20]
	44	Pantelleria		AS	70	100	Offshore banks and seamounts	nd	nd	[20]
	45	Northern Levanzo Island	Tyrrhenian Sea	AS	235	250	Deep areas	nd	nd	[29]
	46	Stromboli	Tyrrhenian Sea	AS	52	58	Shelf	Rocky bottom	nd	[20]
	47	Stromboli	Tyrrhenian Sea	LG	187	345	Deep areas	Rocky bottom	nd	[30]
	48	NE Stromboli	Tyrrhenian Sea	AD, PL	129,202	349, 202	Shelf edge and upper slope	Rocky bottom	nd	[30]
	49	Linosa	Sicily channel	AS	160	160	Shelf	Bench terrace	nd	[31]
	50	Linosa	Sicily channel	LG	200	200	Shelf edge and upper slope	Bench terrace	nd	[31]
	51	NE Lipari	Tyrrhenian Sea	AS	83	130	Shelf	Rocks encrusted by coralline algae	nd	[30]
	52	NE Lipari	Tyrrhenian Sea	AS	612	612	Deep areas	Rocky bottom	nd	[30]
	53	NE Lipari	Tyrrhenian Sea	PL	129	158	Shelf	Rocks encrusted by coralline algae	nd	[30]
	54	NE Lipari	Tyrrhenian Sea	AD	129	218	Shelf edge and upper slope	Rocks encrusted by coralline algae	nd	[30]
	55	SW Lipari	Tyrrhenian Sea	AD	207	298	Shelf edge and upper slope	Rocky bottom	nd	[30]
	56	Salina	Tyrrhenian Sea	PL	129	345	Shelf edge and upper slope, deep areas	Rocky bottom	nd	[30]
	57	Panarea	Tyrrhenian Sea	LG	187	345	Deep areas	Vertical rocky walls	nd	[30]
	58	SE Panarea	Tyrrhenian Sea	AD, PL	351,349	351,349	Deep areas	Vertical rocky walls	nd	[30]
	59	NW Filicudi	Tyrrhenian Sea	AD, LG	647	647	Deep areas	Rocky bottom	nd	[30]
Campanian	14	Vedove Shoal (Capri)	Tyrrhenian Sea	LG	240	260	Deep areas	Deep rocky banks	Lost garbage	[24]
	15	Bay of Naples	Tyrrhenian Sea	AD, AS	200	200	Shelf edge and upper slope	Rocks encrusted by coralline algae	nd	[17,27]
	16	Naple Gulf	Tyrrhenian Sea	AF, AS	80	100	Shelf	Rocky bottom	nd	[17,32]
	17	Capri Island	Tyrrhenian Sea	AS	70	70	Shelf	Shoal	Fishing activity	[17,27]
	18	Capri Island	Tyrrhenian Sea	LG	160	260	Shelf edge and upper slope	Rocky bottom	nd	[17,27]

Table 1. *Cont.*

Latium	11	Western Pontine Archipelago	Tyrrhenian sea	LG, PL	194	220	Offshore banks and seamounts	Rocky bottom	Fishing activity	[33]
	12	Western Pontine Archipelago	Tyrrhenian sea	AD, LG, PL	145	155	Shelf edge and upper slope	Rocky bottom	Fishing activity	[33]
	13	Western Pontine Archipelago	Tyrrhenian sea	LG, PL	130	138	Shelf	Rocky bottom	Fishing activity and lost garbage	[33]
Tuscany	7	Montecristo Natural reserve	Tyrrhenian sea	AS, PL, LG	108	200	Shelf edge and upper slope	Shoal	nd	[4]
	8	Mezzo Canale	Tyrrhenian Sea	AS	70	70	Shelf	nd	nd	[34]
	9	Capraia Island	Tyrrhenian Sea	AS	75	90	Shelf	Rocky bottom	nd	[17]
	10	Elba	Tyrrhenian Sea	AS	60	94	Shelf	Rocks encrusted by coralline algae	nd	[35]
Calabrian	19	Scilla	Tyrrhenian Sea	AS	50	100	Shelf	Rocky bottom	nd	[1]
	20	Golfo di S. Eufemia	Tyrrhenian Sea	AD PL AS	70	120	Shelf	Shoal	nd	[2]
	21	Vibo Marina	Tyrrhenian Sea	AD	90	132	Shelf	Shoal	Fishing activity	[27]
	22	Favazzina	Tyrrhenian sea northern border Messina Strait	AS	62	72	Shelf	Rocky bottom	nd	[36]
Apulia	23	Vieste	Adriatic sea	LG	350	350	Deep areas	Rocky bottom	Fishing activity	[37]
	24	Gallipoli	Adriatic sea	AS	70	70	Shelf	Rocky bottom	nd	[17]
	25	S. Maria di Leuca	Ionian Sea	LG	671	790	Deep areas	Rocky bottom	Fishing activity	[12,27,38,39]
	26	S. Maria di Leuca	Ionian Sea	AD	630	640	Deep areas	Rocky bottom	Fishing activity	[39,40]
	27	Torre Inserraglio	Ionian Sea	LG	45	45	Shelf	nd	Fishing activity	[37]
	28	Tremiti Islands	Adriatic Sea	AS	51	80	Shelf	nd	nd	[7,34,41]
	29	Porto cesareo	Ionian sea	LG	100	236	Shelf edge and upper slope	Rocky bottom	Fishing activity	[37]
	30	Porto cesareo	Ionian sea	LG	50	50	Shelf	Rocky bottom	Fishing activity	[37]
	31	Capo Comino	Eastern coasts of Sardinia	AS	54	54	Shelf	nd	nd	[17]
Sardinia	32	SW coasts of Sardinia	Western Mediter-ranean Sea	AD, PL, LG	210	210	Shelf edge and upper slope	Shoal	Fishing activity	[42]
	33	Rocky pinnacles off Carloforte	Sardinian Sea	AD, AS, LG, PL	120	170	Shelf edge and upper slope	Rocky bottom	Fishing activity and lost gabage	[43]
	34	Northern edge of Skerki Bank	Sardinian Channel	LG	520	650	Deep areas	nd	nd	[29]
	35	Western Carloforte Island	Sardinian Sea	LG	70	130	Shelf	nd	nd	[35]
	36	Posada canyon	Sardinian Sea	AS	152	156	Deep areas	nd	nd	[21]

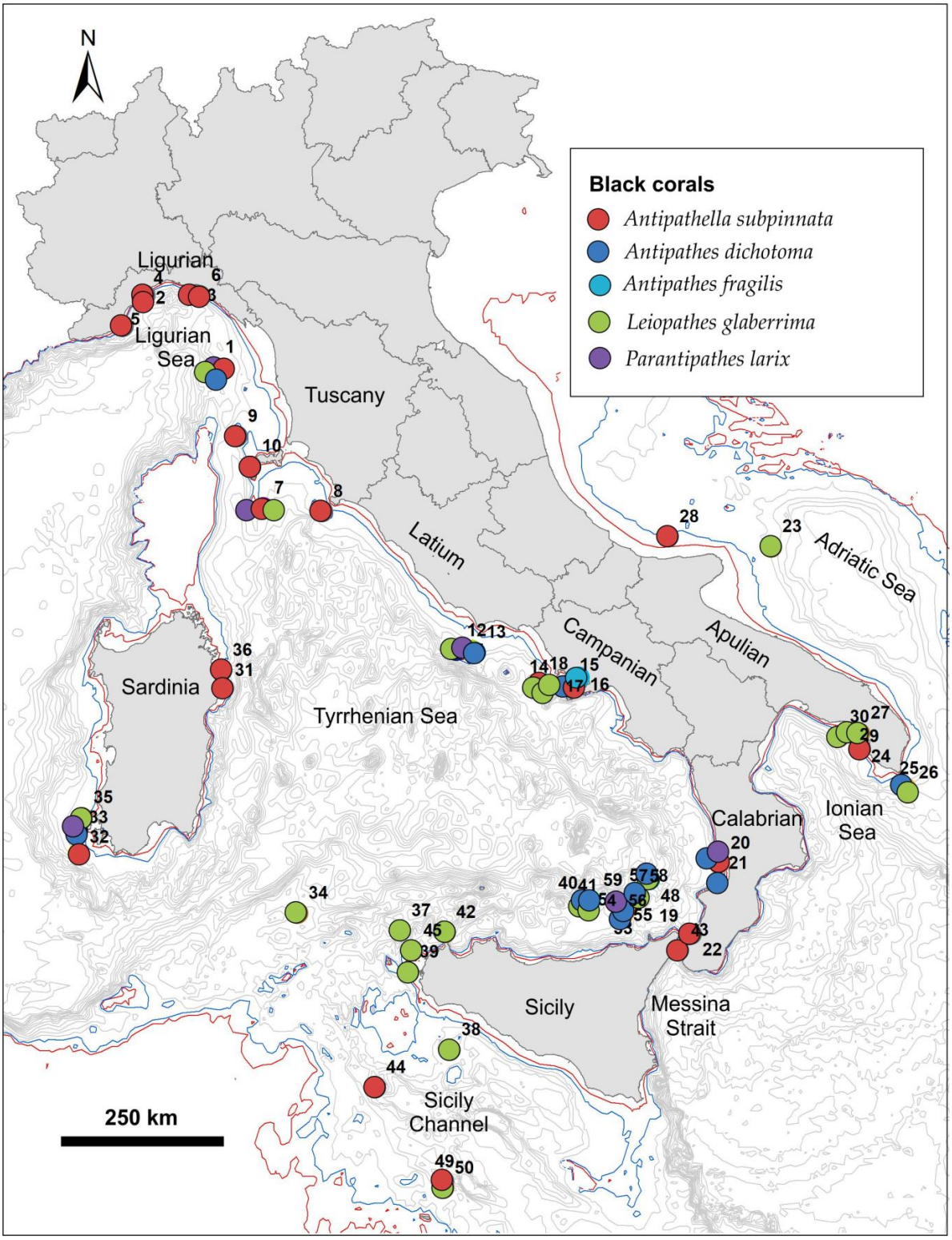

Figure 1. Distribution map of black corals in the Italian seas (red lines: 50-m isobaths; blue lines: 100-m isobaths; grey lines: isobaths of each 200 m interval). Number codes refer to the ID codes reported in Table 1.

3. Results

3.1. The Distribution of Black Corals in the Italian Seas

This study shows the occurrence of black-coral communities composed of *A. subpinnata* (34%), *L. glaberrima* (33%), *A. dichotoma* (17%), *P. larix* (15%), and *A. fragilis* (1%) in 59 Italian sites (Figure 2), which are reported from the Ligurian, Tuscany, Latium, Campanian, Apulian, Calabrian, Sicily, and Sardinia regions (Table 1).

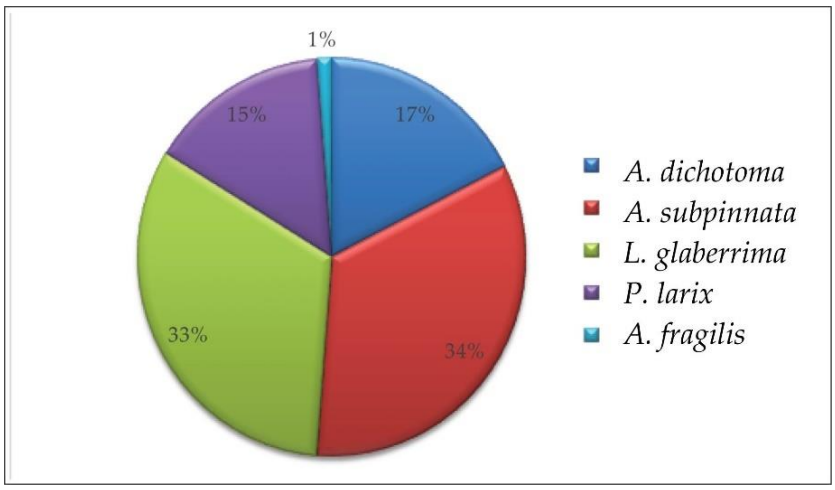

Figure 2. Percentages of black coral species observed in the Italian Seas.

The majority of these sites are located in the Sicily region (23 sites) followed by the Apulian (8 sites), Ligurian and Sardinia (6 sites), Campanian (5 sites), Calabrian and Tuscan regions (4 sites), and Latium (3 sites). Black coral communities were not reported from the central–northern Adriatic Sea.

The bathymetric distribution of black corals in the Italian seas ranges from 42 m to 790 m depth. The shallowest record is found in the Calabrian Region and the deepest one in the Apulian. In the first case, the identified coral is represented by *A. dichotoma,* and in the second one, by *L. glaberrima*.

The analysis of their bathymetric distribution (Figure 3) highlights that the corals *A. dichotoma* and *L. glaberrima* have a deeper distribution (depth ranges (min 250 m–max 243 m, respectively), whereas *A. subpinnata* has a shallower one (medium depth of 115 m).

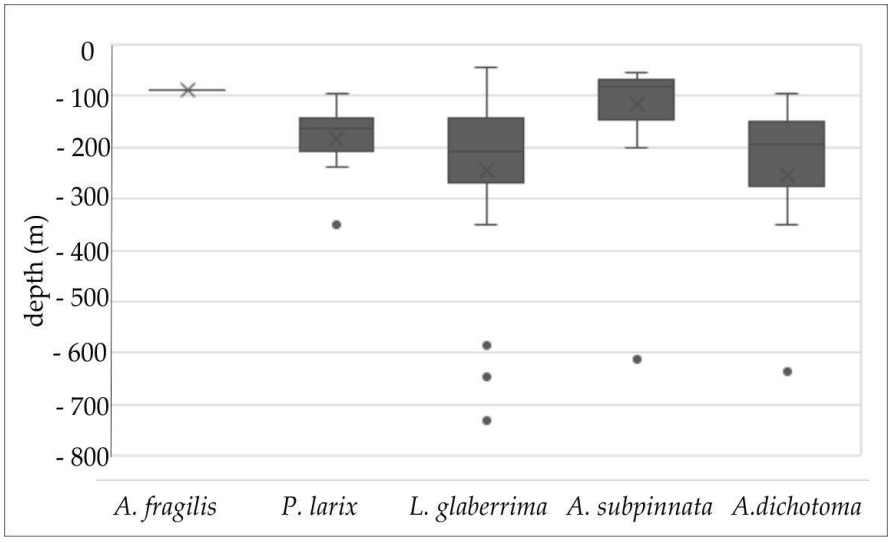

Figure 3. Bathymetric distribution of five black corals in the Italian seas (Outliers are marked with circles and the mean with x symbol).

In addition, *L. glaberrima* shows the most bathymetric tolerance, ranging from 45 m to 730.5 m water depth. In detail, 62% of the Italian submarine sites are characterized by the occurrence of mixed black coral communities, which are most frequent in depths ranging from 50 m to 200 m.

In the Italian seas, black corals were found in different environmental settings, varying from shelf, shelf edge and upper slope, offshore banks and seamounts, and deep areas (Figure 4a). In detail, *A. subpinnata* displays the widest distribution, occurring in all above-mentioned settings with a maximum frequency on the shelf. *Antipathes dichotoma*, *L. glaberrima*, and *P. larix* are reported from the shelf, shelf edge and upper slope, offshore banks and seamounts, and deep areas. *Parantipathes larix* and *A. dichotoma* mainly occur in the shelf edge and upper slope, whereas *L. glaberrima* in the deep areas. *Antipathes fragils* is only reported from the shelf. The black corals observed in the Italian seas are settled on different exposed substrates represented by the rocky bottom, deep rocky banks, rocks encrusted by coralline algae, shoal, terrace, and vertical rocky walls (Figure 4b). The most common substrate types associated with these corals is represented by rocky bottom. A minor percentage, excluding *A. fragils*, were also associated with shoal, deep rocky banks, and rocks encrusted by coralline algae. Finally, in very few cases they were occurring on terraces and vertical rocky walls (Figure 4b).

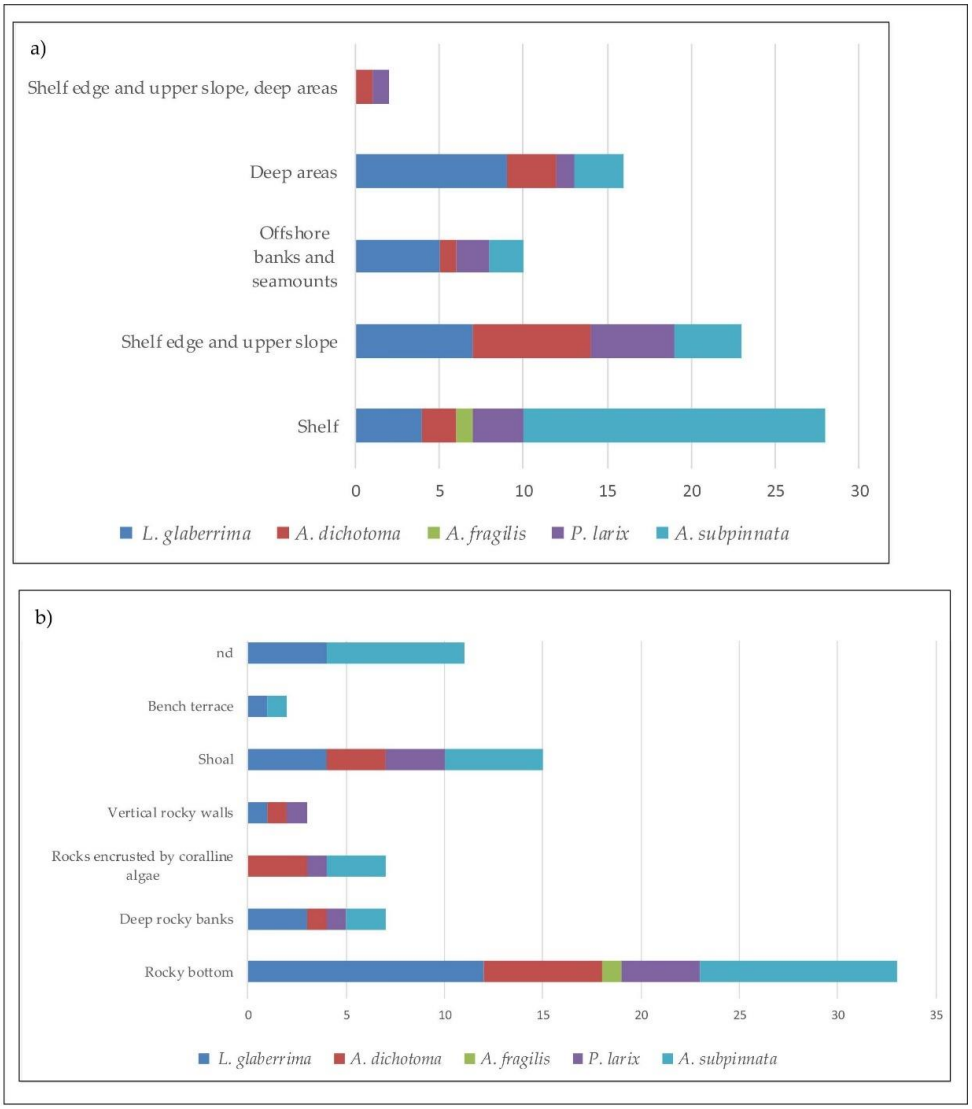

Figure 4. (**a**) Different settings and (**b**) substrate types where black corals were observed in the Italian seas.

3.2. Anthropogenic Impact

The analysis of all the reported sites (Table 1) has permitted the identification of the different anthropogenic impacts affecting the Italian sites where the black corals are settled (Figure 5).

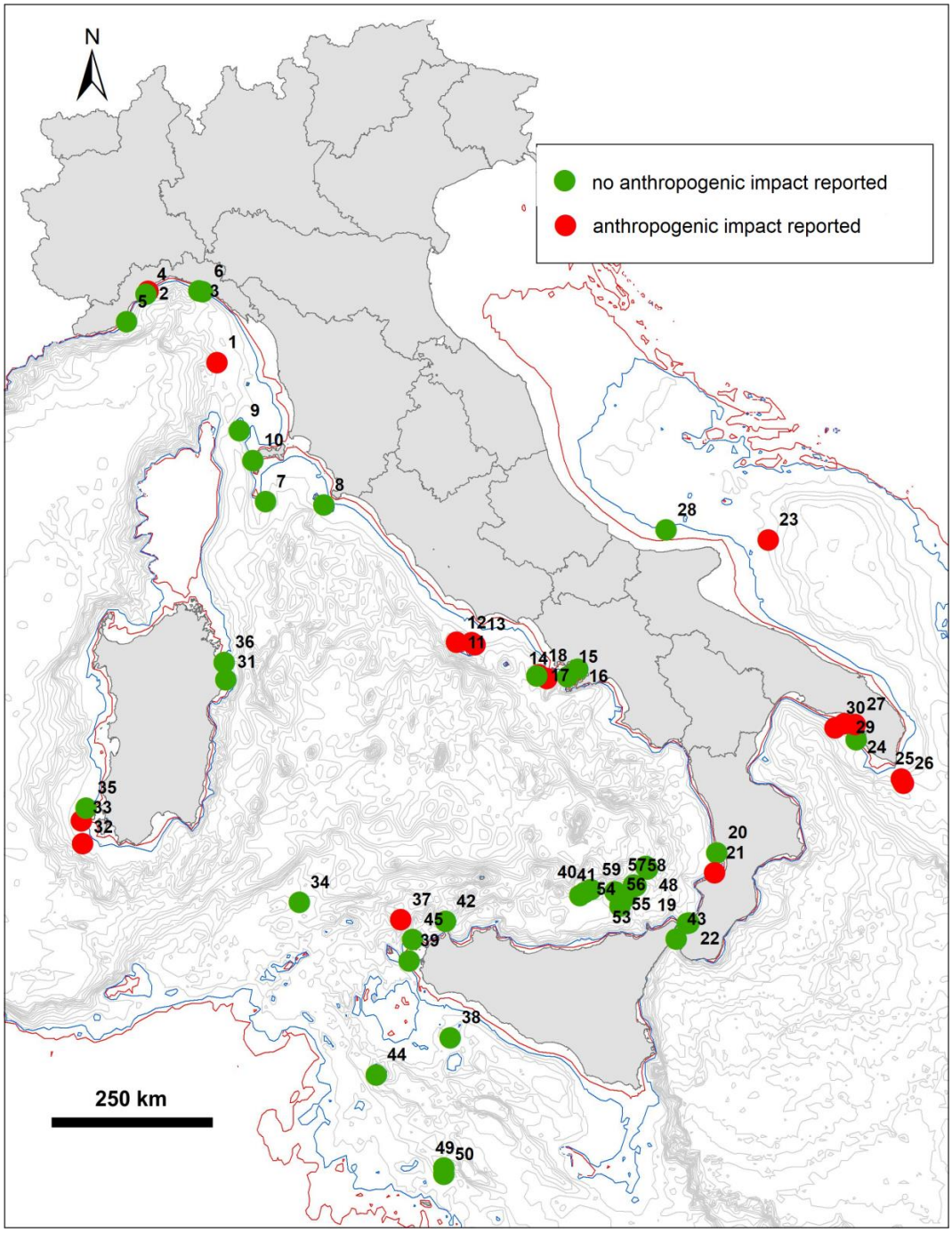

Figure 5. Map of the Italian black coral communities that are affected or unaffected by anthropogenic impact.

These sites, representing 29% of the total, are found in water depths ranging from 45 m to 730.5 m (with a medium depth of 200 m), and are associated with the rocky bottom, deep rocky banks, and shoal substrates. The items affecting the black coral communities are represented by two main categories (Table 1): fishing activity (trawl and ghost nets, longlines, lines, ropes, other fishing litter) and lost garbage (e.g., plastic and metal objects).

A total of 83% of debris impacting the Italian sites is associated with fishing activity, whereas a few exceptions are related to lost garbage (Table 1).

4. Discussion

Black corals have for a long time been considered to be rarest corals in the Mediterranean Sea [3]. The recent increase in the use of modern technological tools, such as ROVs, has permitted the documentation of the great variability of the coral communities occurring in Mediterranean environments e.g., [2,27,44,45]. Exploration of the submarine environment by ROV has represented a turning point in the updating knowledge on benthic communities, providing a valuable tool for the understanding of their geographical and bathymetrical distribution, and their morphological description and ecological aspects [17,46].

Our study is focused on the distribution analysis of the antipatharian corals already reported in the Italian seas. This first step highlighting the presence of the black corals should be considered more common than what supposed. The present review strongly supports the idea proposed by Bo et al. [47], that black corals are among the most conspicuous and widely distributed organisms of mesophotic Mediterranean coral communities (especially in a depth range from 60 m to 150 m). It is also confirmed that the majority occur on rocky bottom and shoals [45]. This statement could be due to the occurrence, in the mesophotic zone, of more favorable environmental factors able to enhance coral growth (which are lower levels of competition for space, food supply, temperature, currents rich in suspended matter, heterogeneity of substrate, rate of sedimentation [47]). According to present knowledge e.g., [1,45,47–49], currents rich in suspended matter are probably the major environmental factor influencing black coral settlement and composition in the Italian seas.

Nevertheless, it is important to consider that shallow water was investigated more by manned submersibles, ROVs, and multibeam echo-sounders than deep water. Deep marine environments could represent an optimal habitat for the settlement of black corals [47]. Such environments are more sheltered from physical damages (e.g., strong storm induced waves [50]), and they are less influenced by seasonal variability. In fact, during the summer, the effect of high irradiance induces strong water-column stratification resulting in a depletion of food supply [51]. In addition, considering the worldwide black coral distribution [52], it is possible to assert that they are typically found in deeper waters, below the photic zone [53], with over 75% of described species occurring down to a 50 m depth [54]. This evidence accentuates the need of increasing knowledge regarding their ecological aspects, which to date are still scarse [49]. Distribution of antipatharian corals along the rocky bottom and shoals may be favored by the combination of both biotic and abiotic factors. The geomorphological characteristics associated with these substrates create a very high variability at a small spatial scale, promoting benthic biodiversity. In addition, low sediment accumulation rate and high bottom current acceleration increase the food supply [43,55,56], favoring the development of the black coral communities.

According to Bo et al., [17], the most frequent black coral species occurring in the Italian seas is *A. subpinnata* [5], followed by *L. glaberrima*, *A. dichotoma*, *P. larix*, and *A. fragilis*. The frequencies of some of these corals (e.g., *L. glaberrima*) may depend on a nutrient enrichment due to anthropogenic eutrophication [57]. Nevertheless, from available data, black corals occur in the vicinity of all the small Italian islands (Favignana, Montecristo, Elba, Capraia, Capri, western Pontine Archipelago, Aeolian islands, Pantelleria, Linosa, Carloforte, and Tremiti islands; Figure 1). In this regard, the theory of island biogeography proposed by MacArthur [58] helps to explain this result. According to this theory, the species richness of natural communities is influenced by different factors, such as habitat heterogeneity and rate of competition. These are both linked to the surface area of the island, larval dispersion and anthropogenic impact. Moreover, the distance from nutrition sources (such as a river mouth) and the degree of their isolation strongly influenced the amount of food supply. In the proximity of topographic structures such as islands or

archipelagos marine currents commonly undergo a velocity increase, providing the right amount of nutrients and representing an optimal marine environment for the growth of black corals.

Anthropogenic Factors Affecting Black Corals

Black corals represent useful indicator species of deep-water marine ecosystems and play an important ecological role as ecosystem engineers [17,49,59]; direct damage linked to anthropogenic impact is frequently reported from the Italian seas e.g., [24,42].

Probably, the occurrence of black corals in Italy on specific types of substrate (mainly rocky bottoms and isolated shoals) as well as their bathymetric distribution (within 50 m and 300 m depth), makes them more exposed to fishing activities, causing damage to vulnerable marine ecosystems. Furthermore, this impact represents a considerable concern, considering their specific characteristics such as 3D structure, long lived species, slow growth rates, and recovery ability [24,60,61]. Fishing impacts (including ghost nets) can lead to the direct removal or partial damage to coral colonies. The skeletons of the damaged corals may become overgrown by various fast growing organisms [4,62]. This kind of damage can have far-reaching and long lasting effects on the population dynamics of Mediterranean black corals, especially when their low growth rates are considered [42]. Despite of the distance from the coast, it is well known that rocky bottoms and isolated shoals are considered important targets for fishermen [24]. In addition, other factors are well known to influence fishing efforts [24,63,64], such as their depth, topography, and the fact that they could represent a refuge for many commercial species. The different entities of fishing disturbance could also be linked to different coral morphologies. In fact, the morphological characteristics (arborescent and erect structures) and the grade of flexibility of black corals may increase their resistance to mechanical friction, showing different mechanical responses to their entanglement [24,43,65].

Finally, it is also important to highlight that in the last decades, all seas have experienced significant changes due to pollution and global warming [66]. These changes can result in mass coral mortality events and quantitative alterations in the composition of benthic communities [67].

Despite all this evidence, the only Italian MPA, containing black coral forests, is the Tremiti Islands Marine Protected Area [7]. All these findings indicate the need for actions focused on the implementation of effective management and proper conservation measures to preserve the Italian antipatharian corals.

5. Conclusions

This study presents an update of the current knowledge regarding the black coral distribution across Italian seas. For the first time, a distribution map is given of black corals occurring in the Italian seas. An analysis of their distribution shows a major bathymetric interval from 60 m to about 150 m (mesophotic zone) and wide occurrences along all the Italian coasts, except for the central–northern Adriatic Sea. It is also highlighted that the Italian sites where black corals occur probably represent only a small portion of their real number. This suspicion suggests the need of further investigations, especially in the deep marine environment. Considering that black corals are indicator species of vulnerable marine ecosystems, and that some of the reported sites are affected by anthropogenic impacts, targeted conservation and management measures should be adopted in order to preserve their pristine species assemblages in the Italian seas.

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