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Review

A Review of Rhodolith/Maerl Beds of the Italian Seas

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Abstract: Coralline algal beds are comprised of biogenic calcareous formations considered a habitat of high conservation interest, hosting a high great biodiversity. To assess the status of this habitat in the Italian seas, we report results from a systematic analysis of the available scientific literature. Italian rhodolith/maerl beds are reported on 31 Italian sites mostly located around islands, shoals, banks, terraces, and gentley sloping shelves, from 9 m to 130 m water depth (with a mean depth of about 56 m). The dominant species occurring in the Italian submarine sites are *Phymatolithon calcareum* and *Lithothamnion corallioides*, with a rich associated fauna including sponges, bryozoans, hydrozoans, polichaetes, molluscs, amphipods, gastropods, echinoderms. Despite the high biodiversity characterizing the Italian rhodolith/maerl beds, only seven submarine sites hosting this sensitive habitat are part of Marine Protected Areas (MPAs). This evidence highlights the need for actions focused on the implementation of effective management and proper conservation measures to preserve such precious habitats. Protection of this habitat cannot be effectively provided without access to multidisciplinary data (e.g., geospatial, biological, geophysical, geomorphological data) capable of assessing its spatial distribution and biological characteristics over wide areas. An increased research effort to improve the production of fine-scale distribution maps and monitoring activities is therefore needed.

Keywords: coralline algae; rhodophyta; precious habitat

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1. Introduction

Free living coralline algae (rhodolith or maerl) are distributed worldwide on the continental shelves [1] from tropical to polar [2–4] regions. The algae may form thick beds over sedimentary bottoms from the low intertidal zone to depths of over 250 m [5–7]. Rhodolith/maerl beds are an important hotspot for biodiversity [6,7] providing a three-dimensional setting for several species, also of commercial interest [8,9]. Specifically, the biodiversity associated with Mediterranean coralline algae beds is very high, with about 700 species recorded [10,11], making it one of the most important submarine Mediterranean ecosystems [12–14].

Free-living coralline algae, depending on the size, inner structure, external shape, algal growth forms, and taxonomic composition, are characterized by three different morphotypes: boxwork (usually large and vacuolar), praline (compact and nodular) and branches [15–17]. The main environmental factors controlling the development of coralline algae beds are light, temperature, nutrients, hydrodynamism (i.e., waves and currents), and bioturbation phenomena that avoid the coralline algae being buried by sediments [18–22]. Rhodolith/maerl beds may be considered as a non-renewable resource [7,16] and are in need of important protection and conservation actions. Consequently, the European Union (EU) developed a network of protected areas known as Natura 2000 sites at the end of the twentieth century. In addition, different national and international actions were developed, including the the "Action Plan for the Conservation of Coralligenous and other Mediterranean bioconstructions" (UNEP-MAP, 2008), and the "Good Environmental Status" in EU "Marine Strategy Framework Directive" (Council Directive, 2008/56/EC). In addition, the maerl-forming species *Lithothamnion corallioides* and *Phymatolithon calcareum* are included in Annex V of the European Community Habitats Directive 1992.

The knowledge regarding the distribution of Mediterranean rhodolith/maerl beds is still fragmented and incomplete [11], and wide-scale mapping initiatives are essential for their effective conservation. To this end, Mediterranean rhodolith/maerl beds were recently included among the habitats of special interest within the Marine Strategy Framework Directive (MSFD-2008/56/EC), aiming at achieving the "Good Environmental Status" (GES) of all marine waters by 2020. Monitoring protocols of rhodolith/maerl beds within the MSFD were also adopted by Italy.

The aim of this study was to summarize and update the current knowledge regarding the distribution of the Italian rhodolith/maerl beds, highlighting the urgent need for conservation strategies targeted at the protection of this sensitive habitat and its biodiversity. Finally, information regarding a new submarine site (the Costacuti Shoal, central Tyrrhenian Sea), characterized by the presence of rhodolith/maerl beds, is also presented.

2. Materials and Methods

2.1. Italian Dataset from Literature

From an historical point of view, the first record of rhodolith/maerl beds was reported by [23] in the Naples Gulf (central Tyrrhenian Sea), and since then, rhodolith/maerl beds have been identified in various locations of the Italian seas. The distribution of the Italian rhodolith/maerl beds herein reported (Table 1) is based on the available scientific literature from 1999 to 2023. For each site, the following information was extracted: site, Italian seas, region, setting, substrate, minimum depth, maximum depth, medium depth, algae morphotype (pralines, boxwork, branches), dominant coralline algae species, Marine Protected Area (MPA), and references.

Table 1. Dataset of the Italian submarine sites hosting rhodolith/maerl beds reported in the available scientific literature. The Costacuti Shoal site (ID 27) is herein reported for the first time. Codes used for the Italian seas: STS (Southern Tyrrhenian Sea), SC (Sicily Channel), TS (Tyrrhenian Sea), AS (Adriatic Sea), IS (Ionian Sea), LS (Ligurian Sea). Codes used for the coralline algae species: Pc (*Phymatolithon calcareum*), Lc (*Lithothamnion corallioides*), Lm (*Lithothamnion minervae*), Lv (*Lithothamnion valens*), Pl (*Phymatolithon lenormandii*), Lr (*Lithophyllumn racemus*), Ls (*Lithophyllum stictaeforme*).

ID	Site	Italian Seas	Region	Setting	Substrate	Min Depth	Max Depth	Medium Depth	Morphotype	Dominant Species	Anthropogenic Impact	MPA	Reference
1	Ustica Island	STS	Sicily	Island	Biogenic gravelly-sand	70	100	85	prâlines, boxwork, branches	Lm	Fishing activity	*	[24,25]
2	Marettimo, Egadi islands	SC	Sicily	Island	Biogenic gravelly-sand	46	46		prâlines	Lv, Lm, Pl,	n.d.		[26,27]
3	Lampione Islet, Pelagie islands	SC	Sicily	Island	Sand and sandy mud	45	60	52.5	n.d.	n.d.	n.d.	*	[28]
4	Graham Bank	SC	Sicily	Bank	Coarse sand	90	120	105	n.d.	Pc, Lc	n.d.		[29]
5	Nereo Bank	SC	Sicily	Bank	Detritic bottom	30	50	40	n.d.	Pc, Lc	n.d.		[29]
6	Pantelleria	SC	Sicily	Shoal	Detritic bottom	30	50	40	n.d.	Pc, Lc	n.d.		[29]
7	Linosa	SC	Sicily	Island	Coarse sediments	60	130	95	prâlines, boxwork, branches	Ls	n.d.	*	[28]
8	Salina	STS	Sicily	Island	Detritic bottom	48	48	48	n.d.	n.d.	n.d.		[27]
9	Panarea	STS	Sicily	Island	n.d.	70	70	70	n.d.	n.d.	n.d.		[27]
10	Ischia	TS	Campanian	Island	Fine sediment	50	72	61	prâlines, boxwork	Pc, Lc	Litter and Fishing activity		[30,31]

Table 1. *Cont.*

ID	Site	Italian Seas	Region	Setting	Substrate	Min Depth	Max Depth	Medium Depth	Morphotype	Dominant Species	Anthropogenic Impact	MPA	Reference
11	Cilento	TS	Campanian	Terrace	Fine and coarse sediments	42	65	53.5	prâlines, branches	Lc, Pc	n.d.		[30–32]
12	Miseno Bank	TS	Campanian	Bank	Coarse sediments	35	58	46.5	branches	Lc	n.d.		[33]
13	Secchitiello	TS	Campanian	Shoal	Fine sediment	68	72	70	prâlines	Lc	Litter and Fishing activity		[30,31]
14	Punta Campanella	TS	Campanian	Shelf	Coarse sediments	52	62	57	prâlines	Lm	Litter and Fishing activity		[30,31]
15	Capri	TS	Campanian	Shelf	Coarse sediments	40	59	49.5	prâlines	Lm	Litter and Fishing activity		[27,30,31]
16	Elba	TS	Tuscany	Island	Detritic bottom	45	45	45	branches	Lc, Pc	n.d.		[34]
17	Giglio	TS	Tuscany	Island	Sand	35	35	35	boxwork	Lc	n.d.		[35]
18	Gorgona	TS	Tuscany	Island	Sand	40	100	70	n.d.	Lc	n.d.		[36]
19	Asinara	TS	Sardinia	Shoal	Biogenic sand	30	30	30	prâlines	Pc	n.d.	*	[37,38]
20	Capo Carbonara	TS	Sardinia	Shoal	Coarse sediments	45	60	52.5	prâlines, boxwork	n.d.	n.d.	*	[17]
21	Tremiti	AS	Apulia	Shelf	Rock	15	48	31.5	prâlines, boxwork	Lr	n.d.	*	[39]
22	Gallipoli	IS	Apulia	Shelf	Rock	36	45	40.5	branches	Lr	n.d.		[39]
23	Armeleia	IS	Apulia	Shoal		35	41	38	branches	Lc	n.d.		[39]
24	Otranto	AS	Apulia		n.d.	38	44	41	branches	Lr	n.d.		[39]
25	Gulf of Venice	AS	Veneto	Shelf	Rock	25	25	25	n.d.	Lc, Pc, Lm, Lr	Fishing activity		[40,41]
26	Gulf of Trieste	AS	Friuli Venezia Giulia	Shelf	Fine sediments	9	24	16.5	branches	Lr	n.d.		[41,42]
27	Costacuti Shoal	TS	Latium	Shoal	Sand	45	50	47.5	prâlines, boxwork, branches	n.d.	Fishing activity		This study
28	Western Pontine	TS	Latium	Terrace	Coarse and fine sediments	65	130	97.5	prâlines, boxwork, branches	Lr, Lc, Pc,	Litter		[43,44]
29	Santo Stefano	TS	Latium	Terrace	Coarse and fine sediments	94	104	99	n.d.	n.d.	n.d.		[27]
30	Portofino	LS	Ligurian	Shelf	Sand	16	104	60	n.d.	n.d.	n.d.	*	[45]
31	La Spezia	LS	Ligurian	Shelf	n.d.	16	104	60	n.d.	n.d.	Fishing activity		[45]

All the sites reported in Table 1 were used to create the first distribution map of rhodolith/maerl beds in the Italian seas.

2.2. General Setting of the New Site and Data Available

The Costacuti Shoal (ID 27 in Table 1) is located on the Latium continental shelf about 40 km off Capo d'Anzio Promontory (central Tyrrhenian Sea). The shelf is affected by a microtidal regime [46] and sediments are mainly supplied from fluvial input and the reworking of relict sediments during the Holocene [5,47]. The Costacuti Shoal, located in a water depth ranging between 48 and 36 m, is elongated in a NW-SE direction and has a width of 250 m wide, a length of 1600 m, and a height of 10 m with respect to the surrounding seafloor. The shoal is characterized by the presence of *Posidonia oceanica* meadows and coralligenous reefs [48,49]. A heavily exploited trawling fishing ground is also observed offshore by the coasts of Anzio [50].

2.2.1. Geophysical Data

Geophysical data include both high-resolution multibeam bathymetry and side-scan sonar data collected through Reson SeaBat 8125 (working at a frequency of 455 kHz) data and Klein 3900 (working at a frequency of 455 kHz) systems, respectively. Data were acquired between December 2017 over an area of about 25 km^2 surrounding the Costacuti Shoal. Processing of raw data was performed to produce a digital elevation model (DEM) with a cell size of 2 m (Figure 1) and a mosaic of backscatter intensity with 0.2 m resolution (Figure 1b). The analysis of geophysical data allowed for the identification of seafloor areas hosting rhodolith/maerl beds.

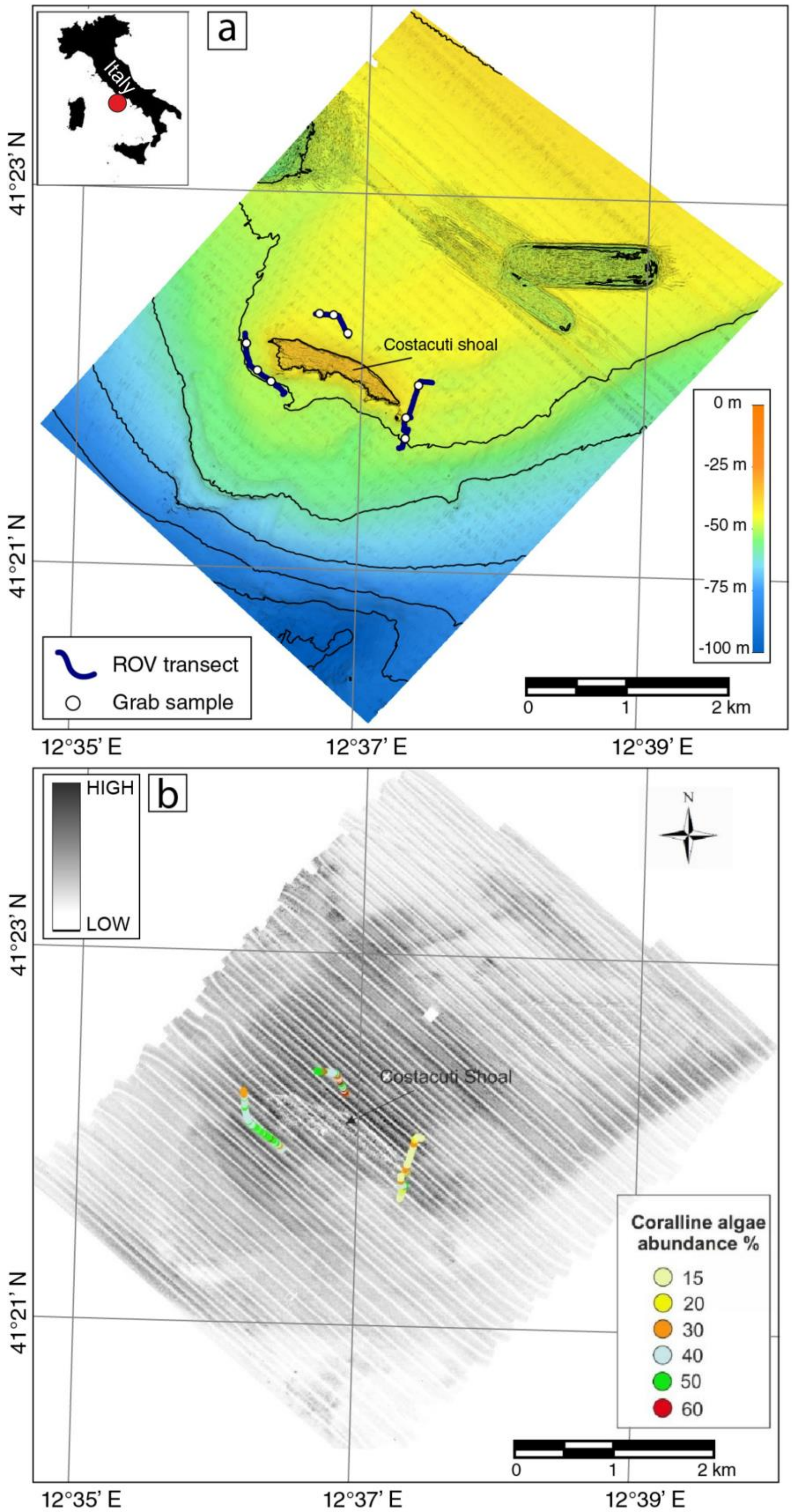

Figure 1. (**a**) Shaded relief map of the seafloor around the Costacuti Shoal showing the location of ROV transects and grab samples (insert with location of the new site, red dot); and (**b**) side-scan sonar mosaic of the Costacuti Shoal with location of video transects showing the percentage abundance of the coralline algae along the tracks.

2.2.2. Ground-Truth Data

Ground-truth data included ROV videos and grab samples collected in January 2018 on board the small vessel "VegaUno". The ROV, Pollux III (Global Electric Italiana), was equipped with a Sony CCD 1/3" navigation camera, a Sony HDRCX115E high-definition camera and a GoPro camera. The ROV was equipped with laser pointers (with a laser beam spacing of 20 cm) to provide references for scale and an ultra-short baseline positioning system (USBL) to provide a record of the navigation track.

Three video transects (Figure 1a and Table 2) were acquired on shelf sectors adjacent to the shoal. These were used to characterize the seafloor texture and the biological communities inhabiting the seafloor, and to assess their environmental status. In addition, the abundance percentage cover of the coralline algae cover was estimated along each track. Specifically, image frames were extracted every 30 s of the footage and percentage coverages were visually estimated for each frame, according to classes of percentage coverage (i.e., <15; 20; 30; 40; 50; >60%).

Table 2. List of ROV transects performed around the Costacuti Shoal with an indication of the transect code, length of transect, starting and ending coordinates of transects, and transect depth (m).

Code	Length (m)	Latitude (Start)	Longitude (Start)	Latitude (End)	Longitude (End)	Depth (m, Start-End)
S1	550	41.37071082°	12.61497847°	41.37256383°	12.61105010°	45–45
S2	212	41.36361100°	12.62258272°	41.36334395°	12.62184302°	44–45
S3	265	41.36537945°	12.60748005°	41.37068328°	12.60282734°	50–49

Nine grab samples (Figure 1a and Table 3) were collected with a 20 L Van Veen grab. Sediment samples were analyzed for grain size distribution, using dry sieving and a laser particle sizer (0.5 phi interval), and classified according to the Folk classification scheme [51]. Furthermore, the onboard analysis of grab samples allowed for defining the bed thickness.

Table 3. List of grab samples, with an indication of the sampling site code, and the coordinates, and depth (m) from which grabs were made.

Code	Latitude	Longitude	Depth (m)
S1_B1	41.37129642°	12.61459825°	45
S1_B2	41.37238438°	12.61393591°	45
S1_B3	41.37241608°	12.61206103°	45
S2_B1	41.36367024°	12.62238577°	46
S2_B2	41.36595069°	12.62333410°	45
S2_B3	41.36197936°	12.62213928°	49
S3_B1	41.36585067°	12.60682600°	50
S3_B2	41.36686492°	12.60494024°	49
S3_B3	41.36896419°	12.60299915°	49

3. Results

3.1. Coralline Algae Beds in the Italian Seas

This study shows the occurrence of rhodolith/maerl beds in 31 submarine Italian sites (Figure 2) from nine regions of Italy (Ligurian, Friuli Venezia Giulia, Veneto, Tuscany, Latium, Campanian, Apulia, Sicily, and Sardinia). The bathymetric distribution of rhodolith/maerl beds in the Italian seas range from 9 m to 130 m depth (average depth 56 m). The shallowest record (−9 m) was reported from the Trieste Gulf (Adriatic Sea) and the deepest one (−130 m) from the Linosa Island (Sicily Channel). Many of these sites are in the Sicily region (9 sites) followed by the Campania (6 sites), Tuscany and Apulia (4 sites), Latium (3), Sardinia and Liguria (2 sites), Friuli and Veneto (1 site).

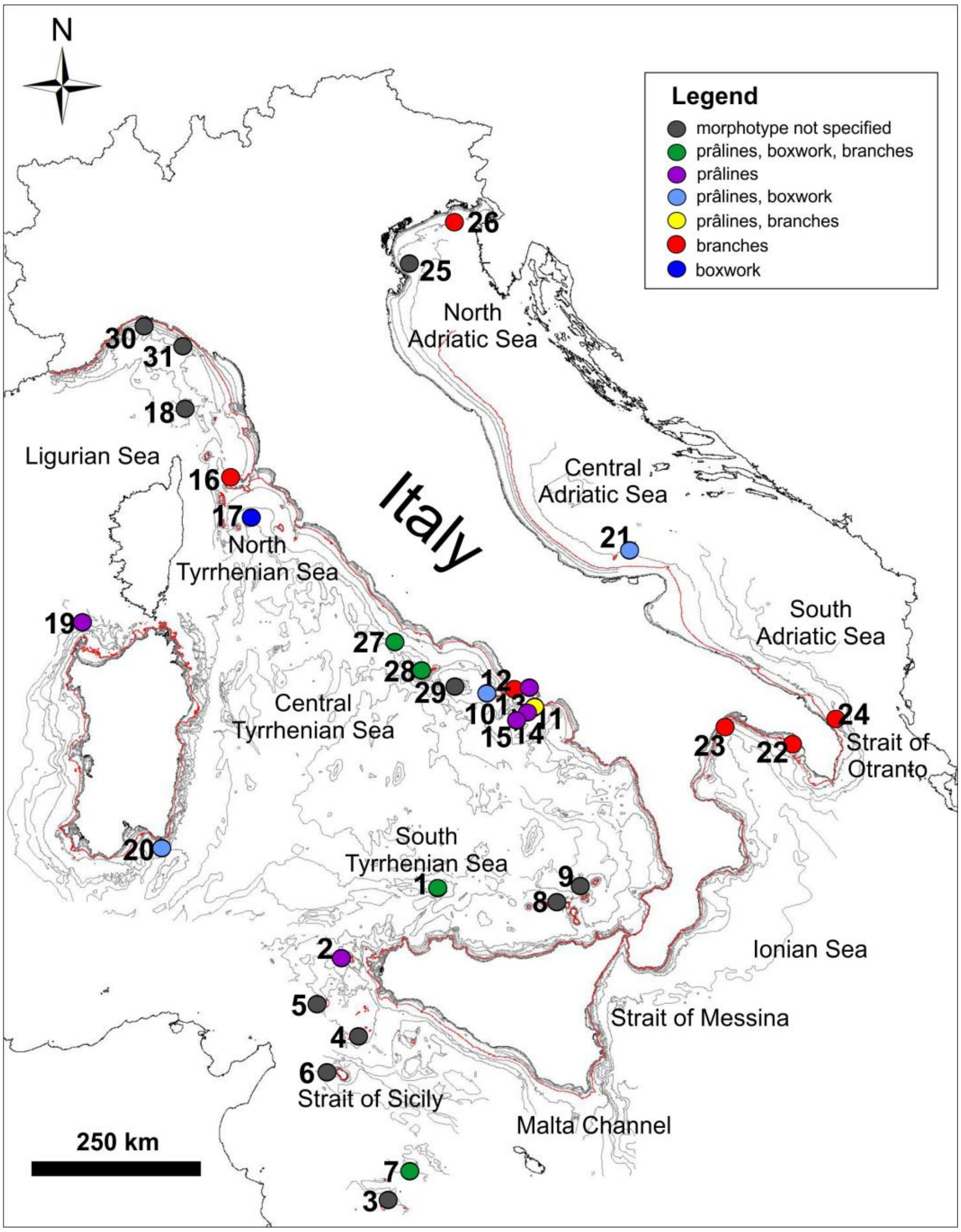

Figure 2. Distribution map of Italian rhodolith/maerl beds with their associated morphotypes (pralines, boxwork, and branches) (red lines: −50 m isobaths; grey lines: isobaths at 200 m interval after −50 m isobaths and at 10 m interval before −50 m isobaths). Numbers codes refer to the identification (ID) sites reported in Table 1.

The Italian rhodolith/maerl beds are represented by three morphotypes (pralines, boxwork, and branches) and these beds are located around islands, shoals, banks, terraces, and over open shelves (Table 1 and Figure 3a). Rhodolith/maerl beds have the widest distribution around islands. In detail, the pralines morphotype displays the widest distribution around islands, shoals, shelves, and terraces. The boxwork morphotype is distributed around islands, terraces, shoals, and shelves, with a maximum frequency in island settings. Branches morphotype is reported from islands, banks, terraces, shoals, and shelves, with a maximum frequency around island settings. The main sediment type associated with the Italian rhodolith/maerl beds is represented by coarse sediments but this habitat is associated with substrates ranging from rocky to fine sediments (Figure 3b). The pralines morphotype is associated with coarse sediment, biogenic gravelly sand, fine sediment, a detritic bottom, and a rock substrate. The boxwork morphotype is associated with rock, biogenic gravelly sand, sand, coarse and fine sediments. The branches morphotype is associated with biogenic gravelly sand, rock, a detritic bottom, and coarse and fine sediments.

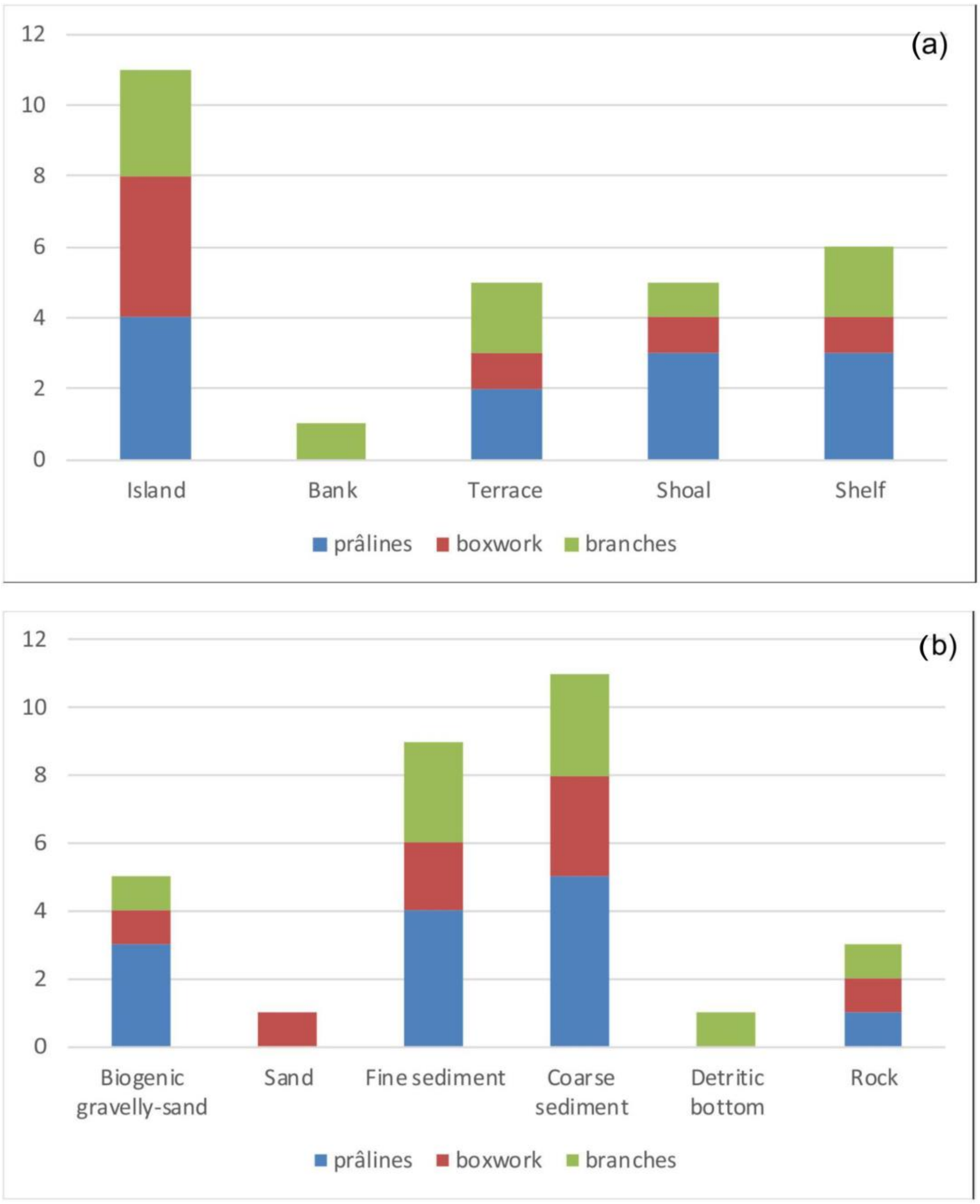

Figure 3. (**a**) Different geomorphological settings; and (**b**) substrate types associated with the different rhodolith/maerl morphotypes.

The main Italian rhodolith/maerl species are represented by *Lithothamnion corallioides* (40%), *Phymatolithon calcareum* (27%), *Lithothamnion minervae* (15%), *Lithophyllum racemus* (9%), *Lithothamnion valens* (3%), Lithophyllum stictaeforme (3%), and *Phymatolithon lenormandii* (3%). In detail, the pralines morphotype includes the L. corallioides, *P. calcareum*, *L. minervae*, *L. racemus*, *L. valens*, *P. lenormandii*, and *L. stictaeforme* species. The boxwork morphotype includes the species *L. corallioides*, *P. calcareum*, *L. minervae*, *L. stictaeforme* and *L. racemus*. The branches morphotype is associated with *L. corallioides*, *P. calcareum*, *L. minervae*, *L. stic-*

taeforme, and *L. racemus*. The most associated fauna of the Italian calcareous algae beds include sponges, bryozoans, hydrozoans, polichaetes, molluscs, amphipods, gastropods, and echinoderms [24,25,28–31,35,36].

The analysis of all the reported sites (Table 1) has also permitted an assessment of the main anthropogenic impacts affecting the Italian sites hosting coralline algae beds [25,30,40,43,45]. These impacts are mainly represented by litter (plastic, grass, wood, and metal objects) and by evidence of fishing activities (trawl marks and ghost net, longlines, lines, ropes, other fishing-related debris). Finally, out of 31 identified sites, only 7 are included in MPAs (Ustica Island, Pelagie islands, Asinara Island, Capo Carbonara, Tremiti Islands, and Portofino marine protected areas).

3.2. Coralline Algae Beds at the Costacuti Shoal (Latium Region)

The seafloor surrounding the Costacuti Shoal, where rhodolith/maerl beds are observed, is characterized by depth values ranging from 45 m to 50 m and by slope values varying from 0 to 0.5°. Video data show that the seafloor along the transects is colonized by pralines, boxwork, and branches morphotypes (Figures 4 and 5).

Rhodolith/maerl beds are present with coverage percentages varying from 15 to 60% (medium coverage percentage 30%), with maximum values observed in the northern sector of the Costacuti Shoal (Figure 5).

Video and grab samples analyses show that the predominant morphotype is represented by pralines. The sedimentological analysis reveals that the sediments associated with rhodolith/maerl beds are mainly composed of gravelly or muddy sand; the percentages of gravelly fractions (including pebbles) range from 3 to 12%, while percentages of mud reach values up to 40% (Table 4). The Costacuti rhodolith/maerl beds host an associated fauna mainly represented by sponges, echinoderms, polichaetes, and anthozoa (Supplementary Material S1). As regards the anthropogenic impacts, trawl marks over the soft bottom hosting coralline algae beds were observed both on the side-scan sonar mosaic and on ROV videos, where local accumulations of coralline algae inside the marks were sometimes observed (Figure 4c,d).

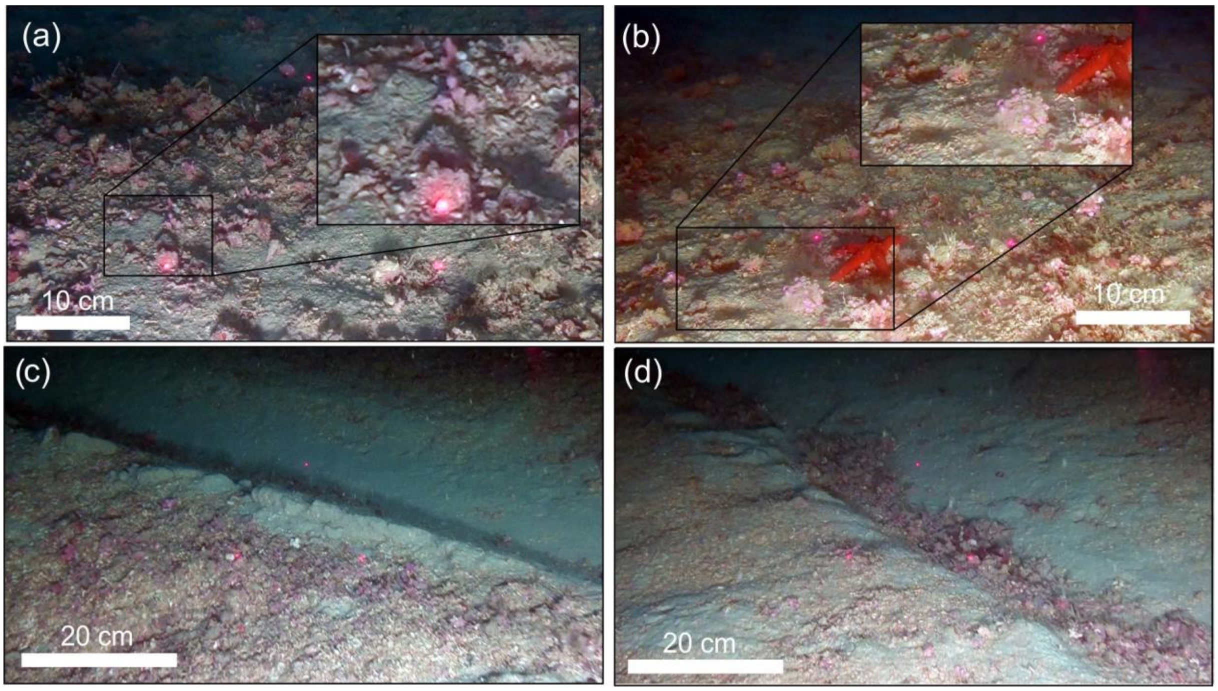

Figure 4. (**a**,**b**) ROV images showing examples of rhodolith/maerl beds observed around the Costacuti Shoal; and (**c**,**d**) ROV images showing occurrence of trawl marks over the soft bottom.

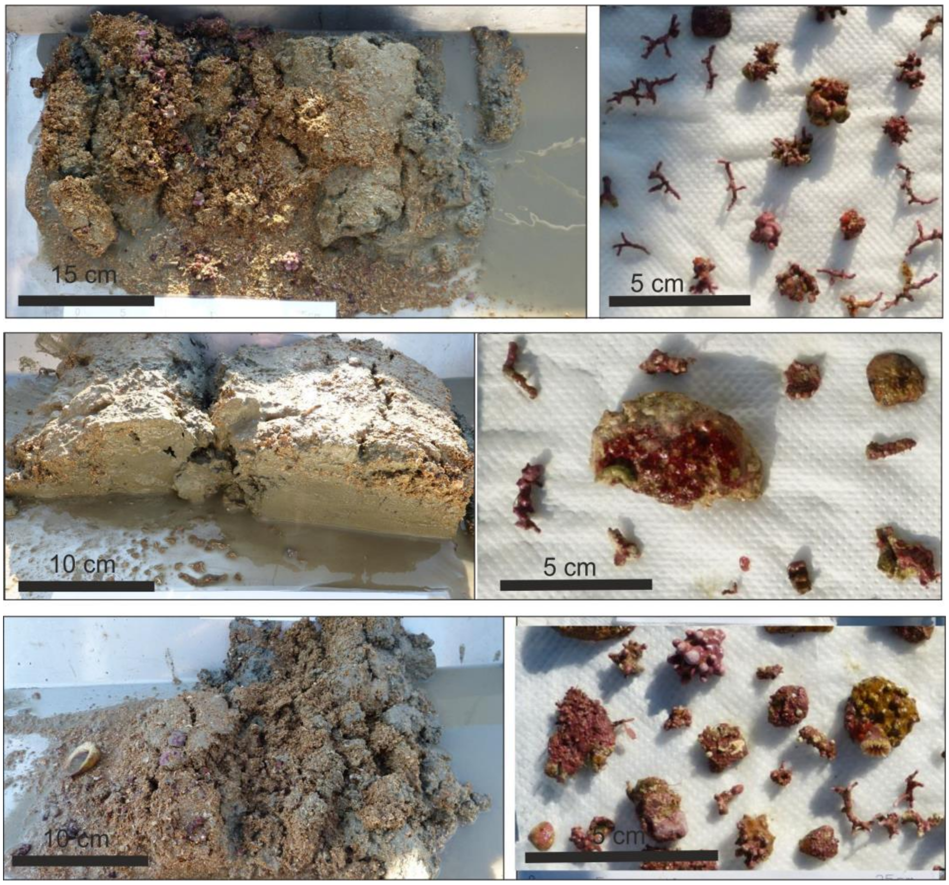

Figure 5. Examples of rhodolith/maerl grab samples recovered along the video transects.

Table 4. Sediment composition of the grab samples recovered around the Costacuti Shoal. (s) slightly.

Code	Depth (m)	%Pebbles	%Gravel	%Sand	%Silt	Folk Class
S1 B1	45	0	3.70	72.38	23.92	(s) gravelly muddy sand
S1 B2	45	0	3.62	70.26	26.12	(s) gravelly muddy sand
S1 B3	45	4.42	3.5	55.04	37.04	Gravelly muddy sand
S2 B1	46	5.63	6.96	81.84	5.57	Gravelly sand
S2 B2	45	1.84	4.97	83.93	9.26	Gravelly sand
S2 B3	49	2.44	3.7	82.24	11.62	Gravelly muddy sand
S3 B1	50	5.30	2.89	51.48	40.33	Gravelly muddy sand
S3 B2	49	5.34	7.51	50.17	36.98	Gravelly muddy sand
S3 B3	49	1.55	3.26	59.54	35.65	(s) gravelly muddy sand

4. Discussion

4.1. Italian Coralline Algae Distribution

This study represents the first attempt to map the distribution of the Italian rhodolith/maerl beds, highlighting their occurrence in all the Italian seas, except for the Messina Strait, likely due to the complex geomorphological characteristics of its seafloor [52]. In the Italian seas, living rhodolith/maerl beds were found from the low intertidal zone to depths of about 130 m, which agrees with the worldwide rhodolith/maerl distributions [5,53]. As already suggested by [10], rhodolith/maerl beds are frequently located around islands and isolated shoals. These settings seem to favor their development due to the combination of both biotic (e.g., associated fauna, bioturbation) and abiotic (e.g., water current, nutrients, sediment input, light penetration, complexity of substrate) factors. The geomorphological characteristics associated with these settings seem to create very high morphological heterogeneity at a small spatial scale, combined with low sediment accumulation rates and enhanced bottom currents [32,54], which promote benthic biodiversity. Although Italian rhodolith/maerl beds over hard bottoms are rare but not absent, we confirmed that the most common substrate suitable for coralline algal development is represented by coarse sediments [5].

The dominant coralline algal species occurring in the Italian submarine sites, are represented by *Phymatolithon calcareum* and *Lithothamnion corallioides*, which are the two species included in the Habitats Directive (92/43/EEC).

In the Mediterranean Sea, the benthic habitats characterized by the highest biodiversity are represented by coralligenous beds, *Posidonia oceanica* meadows [14,55], and rhodolith/maerl beds [10,11,56,57].

The knowledge linked to the latter habitat has only recently increased [1], and available data regarding their distribution, composition, structure, and natural variability, are still inadequate. To fulfill such knowledge gaps, remote-sensing techniques coupled with ground-truth data provide an effective tool for the large-scale assessment of coralline algae spatial distributions, as well as for other pristine benthic habitats e.g., [16,58,59]. Mapping the extent of rhodolith/maerl beds using information from full-area coverage geophysical data, coupled with ground-truth data, represents a first pivotal step for their effective management and conservation. This methodological approach has permitted us to obtain fine-scale information about the coralline algae occurrence at the Costacuti site (Figure 2b).

Overall, the determination of the composition and structure of rhodolith/maerl beds, and therefore of their heterogeneity, represents a crucial aspect of proposing a site as a candidate for conservation measures. Examples of other Italian studies based on the use of this type of approach are the Apulian Continental Shelf [39], the Campania coast [31], the southern coast of Sardinia [26], and off Lampedusa Island [59]. All these above-mentioned studies reiterate the importance of fine-scale distribution maps as an essential step in spatial planning management policy aimed at the conservation of this sensitive habitat. The use of a standard approach (e.g., monitoring protocol for deep Mediterranean RBs, developed within the Marine Strategy Framework Directive—MSFD-2008/56/EC) applied to several sites would allow us to compare all the environmental parameters, which can be considered as drivers in determining the presence of coralline algae beds.

This approach becomes even more relevant if we consider that the Italian seas are a good location for coralline algal growth, being represented by nine biogeographic sectors after [60], including most of the ecological conditions of both western and eastern Mediterranean basins [61], and are therefore characterized by a high ecological and environmental heterogeneity.

4.2. Threats and Conservation

Rhodolith/maerl beds are considered a non-renewable resource e.g., [7] because of their slow growth rate (1 mm/year) and their inability to sustain direct exploitation [6,62]. However, rhodolith/maerl beds are exploited as a source of calcium carbonate and used for a wide variety of economic applications e.g., [1,63,64]. In addition, this habitat can be affected by disturbances of natural (i.e., sediment dislodgment e.g., [65,66] or anthropogenic impacts such as the residuals of water-based drilling fluids discharging during drilling activities [67] and impacts linked to oil extraction activities [68,69].

These beds are also considered sensitive habitats due to their diversity and their potential importance as nurseries for other species [5]. The ongoing rise of water temperatures and ocean acidification act as barriers for the formation and maintenance of coralline algae [62,70], which can also be considered potential climate recorders [5]. These organisms have the potential to provide paleo-climatic records useful to assess the effects of concerning climate variability [71]. For all these reasons, destructive harvesting, and extraction activities by humans should be forbidden in areas hosting such important habitats [72,73]. The analysis of the available scientific literature highlights a lack of studies focused on the potential levels of human pressure affecting coralline algae beds. In fact, only ten studies report data regarding the presence or absence of different human impacts e.g., [25,30,40,43,45]. It is important to note that while the presence of litter and fishing-related debris may represent alternative substrates for algae growth, the secondary effects of marine litter (i.e., the release of compounds on coralline algae) are still largely unknown.

The high heterogeneity of the Italian submarine sites hosting rhodolith/maerl beds, makes the Italian seas a good model for testing different strategic protection initiatives. Despite this unique and high biodiversity, only seven Italian submarine sites are included in MPAs (i.e., Ustica Island, Pelagie islands, Asinara Island, Capo Carbonara, Tremiti Islands, and Portofino Marine Protected Areas).

The importance of coralline algae beds and their high vulnerability to human pressures have been documented worldwide [9,74,75], and today, several legal instruments have been adopted (i.e., Annex V of the Habitats Directive and Marine Strategy Framework Directive (MSFD-2008/56/EC). This study updates the knowledge about coralline algal distributions along the Italian coasts and reports on the main characteristics associated with these sites, highlighting the need for further actions focused on the implementation of effective management and proper conservation measures to preserve this vulnerable habitat.

5. Conclusions

Despite rhodolith/maerl beds being considered hotspot sites of biodiversity that provide a suite of ecosystem goods and services, limited information is available regarding their distribution and ecological role, especially in the Italian seas. This study presents new insights on the coralline algal distributions along the Italian seas, providing information on the main characteristics associated with the Italian sites. The high heterogeneity of the Italian submarine sites makes the Italian seas a good model for the testing of different strategic protection initiatives that, today, are still scarce, as testified by the establishment of only seven Marine Protected Areas. The study also highlighted that the future implementation of effective management and conservation measures to preserve such a precious habitat cannot be effectively gained without access to multidisciplinary data capable of assessing its spatial distribution.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d15070859/s1, Supplementary Material S1. The Costacuti rhodolith/maerl beds host an associated fauna mainly represented by echinoderm, anthozoa, sponge, and polichaetes.

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