

Article

Assessment of Marine Litter in the Coralligenous Habitat of a Marine Protected Area along the Ionian Coast of Sicily (Central Mediterranean)

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Abstract: In the Mediterranean Sea, the coralligenous is an extremely important habitat for its biodiversity and role in carbon sequestration. However, coralligenous biocenosis is sensitive to many anthropogenic impacts, among which one of the major threats is the marine litter. The aim of the present work was to evaluate the marine litter present in the coralligenous habitat of the Marine Protected Area (MPA) Isole Ciclopi (Sicily, Italy). Through the analysis of frames obtained by Remotely Operated Vehicles (ROV) videos, data on the type of marine litter, grade of organisms' coverage, litter-organism interactions, and seabed coverage of items were gained. Through ROV surveys, a low number of marine litter items was observed and most of them were fishing gears. On the found items there was a high degree of organisms' coverage, which suggests that probably the marine litter was abandoned or lost since a long time. Overall, it was observed that in recent years the fishing activity in the MPA has not affected the coralligenous habitat. The present study represents a baseline for future monitoring programmes, which will be useful to develop protection measures and sustainable fishing, in order to preserve the coralligenous habitat of the MPA.

Keywords: marine litter; coralligenous; MPA isole ciclopi; sicily; ROV

1. Introduction

Coralligenous are habitats of biogenic origin, principally constituted by Rhodophyta macroalgae belonging to the order Corallinales [1]. They develop on rocky coasts or sandy planes, under stable conditions of temperature, salinity, and currents, where irradiance level is reduced down to 0.05–3% of the surface irradiance [2]. Coralligenous assemblages are particularly important in the Mediterranean Sea for their extent, biodiversity, and role in carbon dynamics [1,3,4]. These structurally complex and permanent bioconstructions provide heterogeneous habitats and attractive substrate for the settlement of many invertebrate species and sessile organisms [3,5]. Due to their value, coralligenous bioconstructions are among the most important habitats of the Mediterranean Sea and are protected by different international conventions (Habitat Directive 92/43/EEC; SPA/BIO Protocol; Barcelona Convention; Berne Convention; European Union 1967/2006 Regulation). Nevertheless, the coralligenous biocenosis is subjected to anthropic impacts, being maintained by a delicate balance between bioconstruction and bioerosion, which can be easily disturbed by environmental changes [6]. In particular, according to [7], many anthropic activities, such as fishing, have negative effects particularly on hard bottom benthic communities. In fact, fishing gears and marine litter produce an impact when they are abandoned in the environment, with a large variety of marine organisms damaged by entanglement and ingestion [8–18]. For this reason, the pollution of marine waters

by anthropogenic litter has been identified as a serious global environmental problem. The first definition of marine litter in the scientific literature was given in the 1960s [19]. According to United Nations Environment Programme/Mediterranean Action Plan (UNEP), Marine Litter is “any persistent, manufactured or processed solid material discarded, disposed or abandoned in the marine and coastal environment”. In Mediterranean, United Nations Environment Programme/Mediterranean Action Plan (UNEP/MAP) developed the Regional Plan on the Management of Marine Litter in the Mediterranean and the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coasts to monitor marine litter through agreed common and candidate indicators. Moreover, within the European Marine Strategy Framework Directive, MSFD (Directive, 2008) [20], “marine litter” represents the 10 Descriptor (D10) for the assessment of the Good Environmental Status (GES) of marine environment which should be achieved, in all European marine waters, by 2020. Despite its ecological value and its vulnerability, there are very few studies on the anthropic disturbances affecting the coralligenous in the Ionian Sea. Therefore, the aim of the present work is to evaluate the source, distribution, and possible impact of the marine litter in a Marine Protected Area (MPA), located along the Ionian coast of Sicily, in order to provide a baseline for future monitoring programmes.

2. Materials and Methods

2.1. Study Area

The study area is located in the MPA Isole Ciclopi (37°33'41" N, 15°09'5" E), between the municipality of Aci Castello and Acireale, along the Ionian coast of Sicily (Italy). In the same area, a Site of Community Importance (SCI) called “Fondali di Aci Castello” has been established. In fact, in this SCI there are an importance priority habitat, *Posidonia* meadows, and two community habitats, submerged and semi-submerged marine caves and reefs, which includes the coralligenous. Geologically, this area is formed by a complex of subvolcanic rocks, mainly consisting of columnar basalts, which were deposited within the “pre-Etnean Gulf”, as well as by effusive submarine products forming extensive fields of pillow lavas [21,22]. From the coastline down to 25–40 m depth, the seabed is characterized by a steep slope, largely consisting of basaltic bedrock and locally of large volcanic blocks. Moreover, the sea bottom is covered by detrital sediments, ranging from gravels to mud, and showing a general increase in the pelitic portion with depth [23]. The coralligenous assemblage of the MPA mainly consists of calcareous Rhodophyta (genera *Lithophyllum*, *Neogoniolithon*, *Mesophyllum*, *Lithothamnion*, etc.), soft thallus Rhodophyta (genera *Peyssonellia*, *Kallymenia*, *Rodriguezella*, *Osmundaria*, etc.), Porifera (genera *Axinella*, *Petrosia*, *Crambe*, etc.), Cnidaria (genera *Paramuricea*, *Eunicella*, *Leptogorgia*, etc.) and Bryozoa (genera *Smittina*, *Reteporella*, *Myriapora* etc.).

The MPA, with a total extension of 623 ha, includes three zones with different levels of protection and accessibility (from more severe A to less severe C zone) (Figure 1): in Zone A, the integral reserve zone, only a few activities are allowed (bathing, access by rowing boats to reach the bathing areas and scientific research activities); in Zone B of general reserve are allowed more activities such as sailing, rowing and motor navigation at a speed not exceeding five knots; in Zone C of partial reserve are allowed all activities permitted in zones A and B, motorized navigation on vessel and on boats at speeds not exceeding ten knots [24]. Within the MPA, a small artisanal fishing is carried out, principally using the following fishing gears: gill nets and longlines fishing.

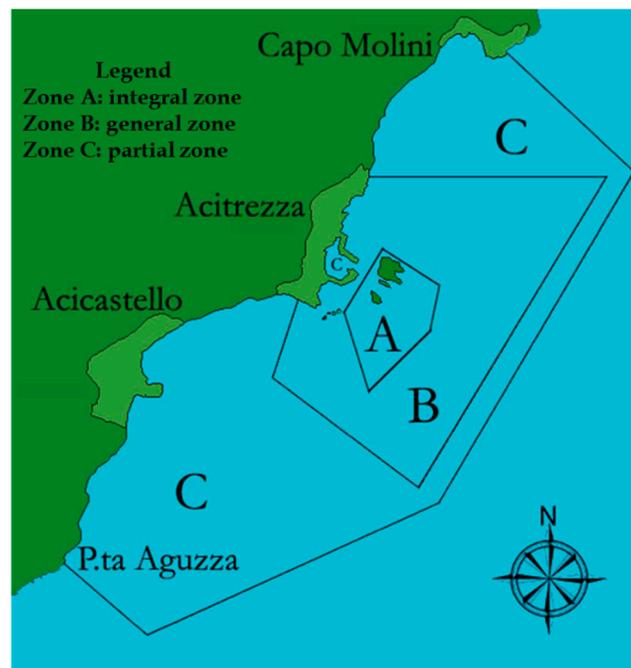


Figure 1. The three protection zones of the MPA Isole Ciclopi.

2.2. Experimental Design

On October 2018, a monitoring activity, through a ROV (Remotely Operated Vehicles), has been carried out in three different transects (TLa, TLb, TLc) of the MPA, on the border of zone A (Figure 2). In fact, in the last few years, studies with ROV were used to monitor deep-sea habitats on a wide area, with non-destructive and standardized protocols, based on computerized analysis of high resolution videos and photos [14,25–27]. ROV investigations have also been successfully performed to obtain quantitative data on benthic marine litter [28–30] and to evaluate the impact of fishing activities through lost gears, in coastal ecosystems [14–18,26,27,31]. The ROV used for this study was Marine Scope, FO II model. The ROV was supplied with a high-definition video camera (GoPro 5), a digital camera with depth sensor and an integrated compass, two laser beams placed 10 cm apart and used as a metric scale for the images and the visual field, and two led strobes of 13,000 lumen.

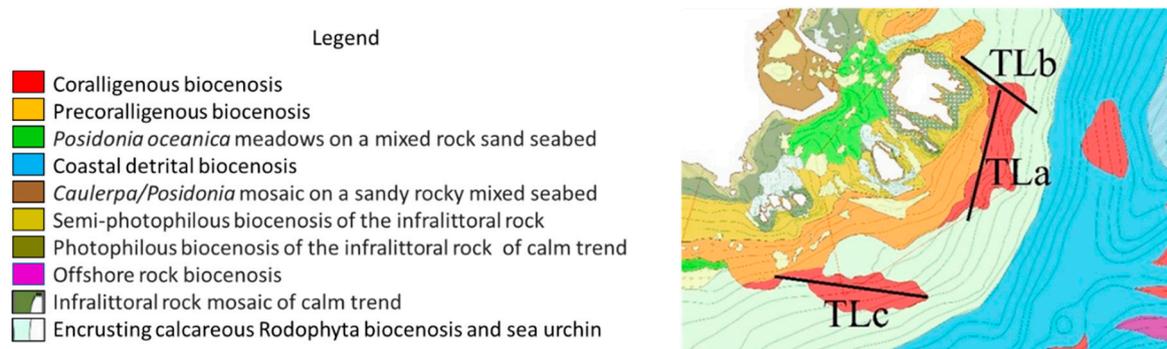


Figure 2. Detail of the three ROV transects. The legend shows the principle biocenosis present in the study area.

The video recorded through ROV, were analyzed by the editing video software AVS Video Editor. According to [19], the marine litter was separated in two groups: “General waste” (Plastic objects, Rubber, Metal, processed Wood, Glass/ceramic, Paper, Textile, other) and “Fishing gear” (Fishing lines, Wire, Rope, Trawl net, Set net, Trap, other). On each item of marine litter, the percentage

of organisms' coverage was visually estimated, following the grades of the Braun-Blanquet's Scale (5 = >75%; 4 = 75–50%; 3 = 50–25%; 2 = 25–5%; 1 = 5–1%; + = <1%), which is generally used for vegetation studies [32]. Moreover, the litter–organism interactions (“No effect” = none interaction, “Entanglement/Coverage” = when organisms were covered or entangled by marine litter but they did not show any visible damage, and “Physical damage” = when specimens were injured or colonies were broken) were observed. In addition, the seabed coverage of marine litter was evaluated, following the classes reported by [19]: “Class 1” (<1 m²), “Class 2” (1–10 m²), “Class 3” (>10 m²). The presence of marine litter was evaluated in terms of density (number of items/100 m²) and frequency (% of total items).

Finally, a drift set net has been collected to assess the macrophytobenthic component and, thus, to compare it with the coralligenous flora present in the MPA. The fishing net that was a gill net of about 5 m in length and 1 m in height was collected during a scientific scuba-dive at a depth of 31 m in the zone A of the MPA. Then, it was stored in a solution of seawater and 90% ethyl alcohol and carried to the Laboratory of Algology of the University of Catania in order to analyse the epiphytic component. Subsequently, only physiologically evident algal species were identified.

3. Results

Through this study, a total of 25 videos were recorded in the three different transects (TLa, TLb, TLc), for an extension of about 200 m for each transect and an average depth of 35 m for the transects TLa and TLc, and an average depth of 33 m for the transect TLb. The analyzed recording minutes were 132 for TLa, 68 for TLb and 87 for TLc. The number of frames obtained were 10 for TLa, 7 for TLb and 4 for TLc. Through ROV videos, a total of 23 items of marine litter has been found: 47.8% of items was found in the transect TLa, 34.8% of items in TLb and 17.4% of items in TLc. The density of items was 5.5 items/100 m² in the transect TLa, 4 items/100 m² in the transect TLb and 2 items/100 m² in the transect TLc (Table 1). In particular, 3 (13.04%) items of “General waste” (Rubber, Block of iron and concrete and Glass bottle) and 20 (86.96%) items of “Fishing gear” (Rope, Fishing line, Set net, Floating rope, and Buoy chain) have been observed (Table 2). Moreover, among the items belonging to “Fishing gear”, those with the highest number of findings were ropes (8 findings) and fishing lines (7 findings) (Table 2).

Table 1. Summary table about the ROV transects.

Transect	Recording Minutes	Number of Frames	Number of Items (Frequency)	Density	Depth Range	Length	Exposure	Latitude and Longitude	
								Initial Point of the Transect	Final Point of the Transect
TLa	132	10	11 (47.8%)	5.5 items/100 m ²	35 m	~200 m	East–South/East	37°33′41.50″ N 15°10′6.26″ E	37°33′34.82″ N 15°10′4.98″ E
TLb	68	7	8 (34.8%)	4 items/100 m ²	33 m	~200 m	North/East–North	37°33′44.02″ N 15°10′1.85″ E	37°33′40.56″ N 15°10′8.73″ E
TLc	87	4	4 (17.4%)	2 items/100 m ²	35 m	~200 m	South–South/West	37°33′25.09″ N 15°09′47.47″ E	37°33′24.79″ N 15°09′56.47″ E

Table 2. Items of marine litter found in this study.

Items	Group of Marine Litter	Number of Findings	Frequencies of the Groups
Rubber	General waste	1	3 (13.04%)
Block of iron and concrete	General waste	1	
Glass bottle	General waste	1	
Rope	Fishing gear	8	20 (86.96%)
Fishing line	Fishing gear	7	
Set net	Fishing gear	2	
Floating rope	Fishing gear	2	
Buoy chain	Fishing gear	1	

Regarding the degree of organisms' coverage on the marine litter, the degree more frequently observed was grade 5 (corresponding to a coverage of at least of 75%). In fact, the coverage grade

corresponding to 5 was present in the 76% of frames, the fourth coverage grade was even to 19% of frames and the third coverage grade was equal to 5% of frames. The coverage degrees corresponding to 1 and 2 were never observed (Figure 3). Furthermore, the interaction between the organisms and the marine litter was estimated and no effect was observed in the majority of frames. Only in four frames, was observed an interaction observed. “Entanglement/Coverage”: the fishing lines were tangled around *Myriapora truncata* (Pallas, 1766) and species belonging to the class of Anthozoa, although without evident damage.

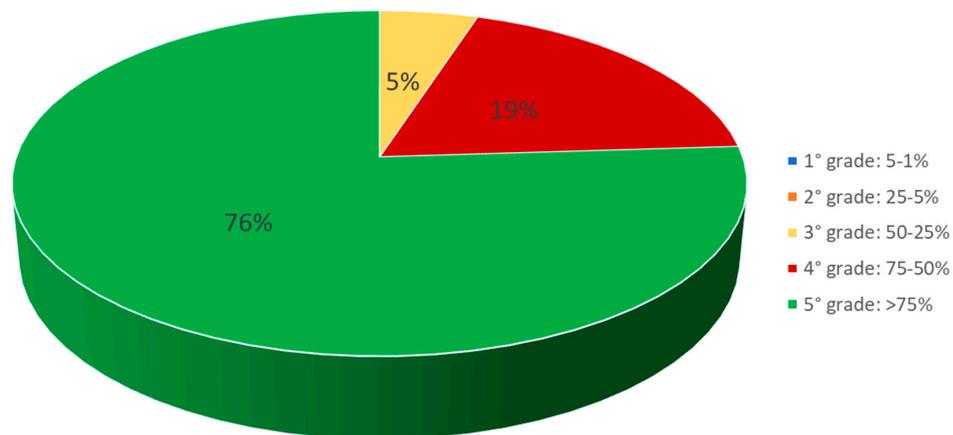


Figure 3. Grades of organisms' coverage on the marine litter.

In the three transects, a difference in the seabed coverage of marine litter was observed. In fact, in the transect TLa, it has been found an equal number of items with a seabed coverage of Class 1 (<1 m²) and of Class 2 (1–10 m²) and only an item with a seabed coverage of Class 3 (>10 m²). Instead, in the transects TLb and TLc the highest number of items had a seabed coverage belonging to Class 1, without any items with a seabed coverage belonging to Class 3 (Figure 4). Furthermore, in the three transects the majority of items of marine litter was included in the group “Fishing gear”, with a low number of items included in the group “General waste”. The transect with a higher number of items of “General waste” was TLb (Figure 5).

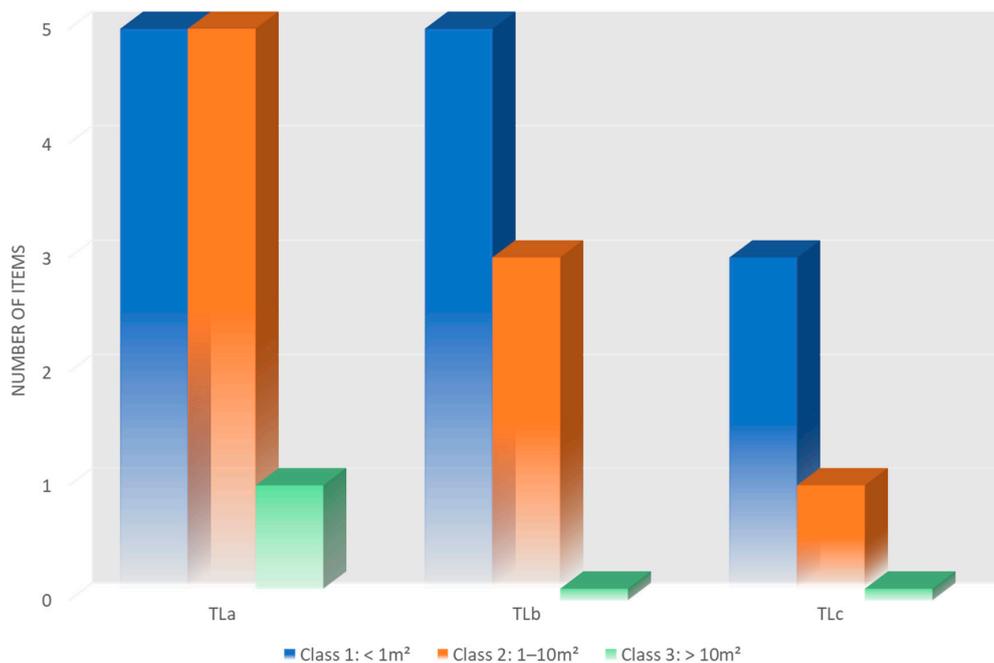


Figure 4. Difference among the three transects in the seabed coverage of marine litter.

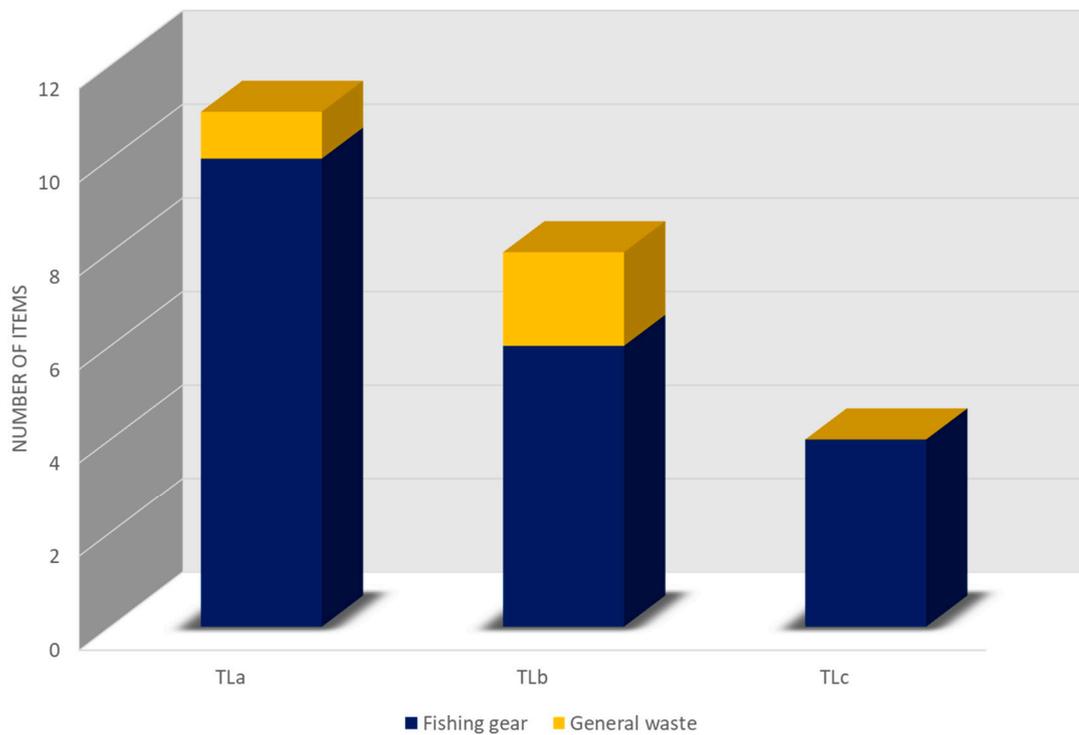


Figure 5. Composition of marine litter in the three transects.

In addition to the analysis of the frames obtained through the ROV, the epiphytic component of the collected drift net has been studied. In total 30 macrophytobenthic *taxa* (as generic level) has been identified (Table 3), divided in: 24 Rhodophyta (80%), 4 Phaeophyceae (13%) and 2 Chlorophyta (7%) (Figure 6).

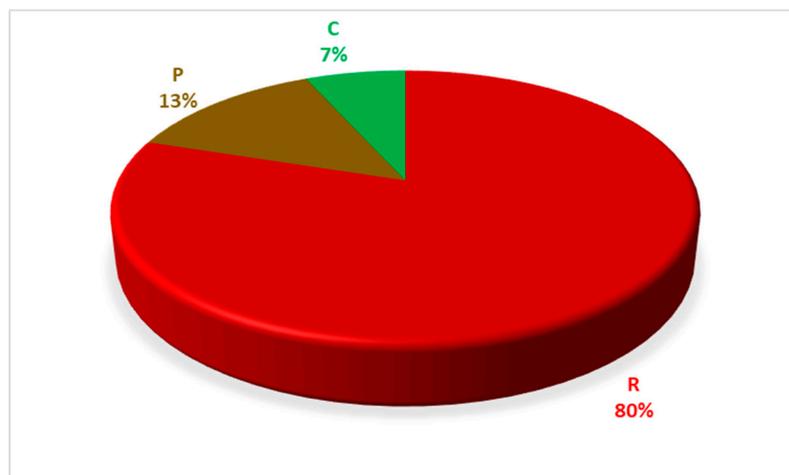


Figure 6. Pie chart showing the percentage of Rhodophyta, Phaeophyta and Chlorophyta present on the drift net.

Table 3. Macrophytobenthic component present on the collected drift net.

Genera.
<i>Antithamnion</i> Nägeli
<i>Apoglossum</i> (J.Agardh) J.Agardh
<i>Caulacanthus</i> Kützing
<i>Ceramium</i> Roth
<i>Champia</i> Desvaux
<i>Contarinia</i> Zanardini
<i>Erythrotrichia</i> Areschoug
<i>Gelidiella</i> Feldmann & G.Hamel
<i>Gloiocladia</i> J.Agardh
<i>Heterosiphonia</i> Montagne
<i>Hydrolithon</i> (Foslie) Foslie
<i>Irvinea</i> Guiry
<i>Jania</i> J.V.Lamouroux
<i>Kallymenia</i> J.Agardh
<i>Lophosiphonia</i> Falkenberg
<i>Mesophyllum</i> Me.Lemoine
<i>Peyssonnelia</i> Decaisne
<i>Phyllophora</i> Greville
<i>Pneophyllum</i> Kützing
<i>Pterothamnion</i> Nägeli
<i>Rhodophyllis</i> Kützing
<i>Rhodymenia</i> Greville
<i>Seirospora</i> Harvey
<i>Spermothamnion</i> Areschoug
<i>Dictyota</i> J.V.Lamouroux
<i>Halopteris</i> Kützing
<i>Lobophora</i> J.Agardh
<i>Sphacelaria</i> Lyngbye
<i>Derbesia</i> Solier
<i>Palmophyllum</i> Kützing

4. Discussion

Marine litter has been globally recognized as an emerging anthropogenic threat in the marine environment in recent decades [30]. For this reason, mapping the distribution and identifying the composition and sources of marine litter is one of the criteria (10.1.2) to achieve GES by 2020 [20,33,34]. Recent studies focused on the marine litter, are increasingly using the video surveys to assess the abundance of litter items on rocky bottoms [30,35]. As a result, in this study, three ROV transects (TLa, TLb, and TLc) were carried out to evaluate the presence of marine litter in the coralligenous habitat of the MPA Isole Ciclopi. In particular, the transect TLa had the highest number of recording minutes, obtained frames and items of marine litter. Instead, the transect TLb had the lowest number of recording minutes because this transect has a different slope exposure and hosts a smaller coralligenous habitat, compared with the other transects. The transect TLc, although presented a high extension of the coralligenous, was the transect with the lowest number of items of marine litter.

During the analysis of frames, a total of 23 items of marine litter were observed and the majority of them belonged to the group "Fishing gear". The items belonging to the group of "General waste" were only three that have been found, one (Rubber) in the transect TLa and two (Block of iron and concrete, Glass bottle) in the transect TLb, respectively (Figure 7). Furthermore, the items of "Fishing gear" were predominantly on rocky bottoms, on rocky outcrops and where the coralligenous habitat was more complex and developed. Instead, the items of "General waste" have been found on sandy bottoms. Indeed, the distribution of marine litter is mainly influenced by the geomorphologic and oceanographic features [36–39]. The general wastes may be transported by currents and rest on soft bottoms. On the contrary, where there are complex reliefs, such as boulders and outcrops, fishing gears

can be damaged or lost [19]. Furthermore, hard bottoms usually are colonized by dense aggregations of sessile fauna increasing the probability for litter entanglement [40], and usually host several important commercial fish species, which represent a preferential target for fishermen [29,40,41].



Figure 7. Two examples of obtained frames: on the left a found item belonging to the group “General waste” and on the right a found item belonging to the group “Fishing gear”.

On the found items of marine litter there was a high degree of organisms’ coverage. In fact, in the 76% of frames there was an organisms’ coverage degree of at least 75% on the marine litter. From the obtained frames, it was observed that the items were largely colonized by encrusting algae belonging to the genera *Mesophyllum*, *Lithophyllum* and *Peyssonnelia*, with a lower coverage of invertebrates of the class Hydrozoa, Anthozoa, Demospongiae, Polychaeta, Gymnolaemata and of the subphylum Tunicata. In fact, despite fishing gears and litter usually are harmful to marine flora and fauna, these anthropogenic products can also provide artificial substratum for sessile organisms [42,43]. Moreover, in most of frames the interaction between organism and marine litter was classified with “No effect”, with only four frames that showed an interaction “Entanglement/Coverage”, without any physical damage.

In all transects, the majority of found items had a seabed coverage belonging to the Class 1 (<1 m²), with only a case, in the transect TLa, of a set net of sizes comprised in Class 3 (>10 m²) abandoned on the seafloor.

Regarding the analysis of the macrophytobenthic component on the collected drift net, a high percentage of Rhodophyta was observed. Indeed, most of the net was covered by encrusting red algae, which are characteristic of dim-light environments and structural components of the coralligenous biocenosis. The high coverage of encrusting algae, with a low growth rate that depends on a low light compensation point, might suggest that the drift net has been on the bottom since a long time.

The present study allowed evaluating the source, distribution, and possible impact of marine litter in the coralligenous of the MPA Isole Ciclopi. Through the analysis of ROV videos, it was seen that on the found items there was a high degree of organism coverage, particularly represented by encrusting algae and in smaller proportion by sessile invertebrates. Therefore, the observed items were probably lost or abandoned a long time ago and were positively used by organisms as a new substrate. Moreover, the analyzed frames showed in most cases a no-effect interaction between marine litter and organisms.

Overall, through data obtained by ROV surveys and laboratory analysis, it was observed that in recent years the fishing activity of the MPA has not affected the coralligenous habitat. The present study represents a baseline for future monitoring programmes, which will be useful to develop protection measures and sustainable fishing, in order to preserve the coralligenous habitat of the MPA.

Author Contributions: The present research was conceptualized by G.A.; L.G.C. performed the SCUBA diving and collected the ROV data; G.M. and L.G.C. processed all the collected data and wrote the manuscript; G.A. reviewed and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflict of interest.

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