Article

Characterization of the Coralligenous Formations from the Marine Protected Area of Karaburun-Sazan, Albania

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Citation: Gimenez, G.; Corriero, G.; Beqiraj, S.; Lazaj, L.; Lazic, T.; Longo, C.; Mercurio, M.; Nonnis Marzano, C.; Zuccaro, M.; Zuna, V.; et al. Characterization of the coralligenous formations from the Marine Protected Area of Karaburun-Sazan, Albania. J. Mar. Sci. Eng. 2022, 10, 1458. https://doi.org/10.3390/jmse10101458

Academic Editor: Jean-Claude Dauvin

Received: 25 August 2022
Accepted: 1 October 2022
Published: 9 October 2022

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Abstract: Coralligenous bioconstructions are one of the Mediterranean’s most distinctive and biodiverse marine habitats. This research aimed to provide a preliminary characterization of macrobenthic coralligenous assemblages at four sites located in the Marine National Park of Karaburun-Sazan in Albania. We analyzed images obtained from videos recorded along underwater transects at two different depths. Over a total of 61 taxa (3 Rhodophyta, 2 Ochrophyta, 6 Chlorophyta, 30 Porifera, 5 Cnidaria, 3 Mollusca, 2 Annelida, 1 Arthropoda, 4 Bryozoa, 6 Echinodermata, and 1 Chordata), 53 were identified at the species level using taxonomic and semi-quantitative video image analysis, thus allowing an update to the Albanian coralligenous species list with 34 new species. This study revealed differences in species richness and composition among the investigated sites and between depths, with a high number of taxa exclusive to one site and a few taxa common to all sites. Seven taxa are protected by law, among which are the echinoderm Centrostephanus longispinus, included in the Bern (Annex II) and Barcelona (Annex II) Conventions and Habitat Directive (92/43 EEC) (Annex IV), and the sponges Spongia (Spongia) officinalis and S. (S.) lamella, included in Annex III of the Bern Convention. Only the alga Caulerpa cylindracea can be considered an alien species. Although preliminary, the present research indicated the occurrence of rich and diversified macrobenthic assemblages in the study area. Moreover, it has been demonstrated that video analysis can provide a biodiversity baseline within MPAs, where traditional methods involving invasive sampling cannot be applied, particularly in areas such as the Albanian coasts, where anthropogenic impacts have been historically significant. Finally, this work provides a first estimate of the structural biodiversity in a recently established marine protected area, thus representing the basis for subsequent monitoring.

Keywords: benthic communities; bioconstructions; Mediterranean; Adriatic Sea; MPA; marine biodiversity

1. Introduction

Coralligenous outcrops are among the richest and most characteristic marine habitats of the Mediterranean [1–3]. They range from about 10 to 120 m in depth and consist of endemic carbonate bioherms mostly built by coralline macroalgae adapted to live in low light conditions [4]. By overlapping their thalli, calcareous algae form complex biogenic frameworks, thus acting as ecosystem engineers (sensu [5]). Furthermore, they
provide space for sponges, bryozoans, and hydrozoans, as well as niches or shelters for many vagile organisms, including molluscs, echinoderms, and polychaetes [1,6].

The associated faunal component plays an important role in structuring these bioconstructions. When light conditions are not suitable to support algal communities, animals can take over the role of the main builders, giving rise to mesophotic reefs built by scleractinians or oysters [7–9]. There is usually a clear spatial separation between substrates dominated by algae or animals, thus creating a complex mosaic of facies in which few dominant species alternate even at a small scale. However, transitional bands where there is a marked presence of animal species with a structuring role are likely to occur in coralligenous formations [1,7,8].

Biogenic substrate development depends on a balance between building and bioeroding processes, with the latter mainly carried out by boring sponges (e.g., Cliona spp.) and molluscs [10]. Overall, builders and bioeroders create high habitat heterogeneity, influencing the abundance and functional diversity of the associated fauna [11] and giving marine bioconstructions the status of biodiversity hotspots [1,4]. Due to its high ecological richness, the Mediterranean coralligenous has been extensively studied, highlighting that it should be interpreted as a complex mosaic of habitats. Indeed, on a large geographical scale, information on the spatial and temporal variations of its biodiversity, as well as the corresponding faunal inventories, is still lacking [12].

The eastern part of the Ionian Sea has been identified by the WWF Mediterranean Program as one of the 10 marine and coastal areas of the Mediterranean that has critical importance for biodiversity [13]. The Contracting Parties of the Barcelona Convention have adopted the Integrated Monitoring and Assessment Program (IMAP), according to which Adriatic countries need to adjust their national monitoring programs [14]. Furthermore, Albania has been listed by UNEP-MAP-RAC/SPA as one of the areas of regional interest [15], for which knowledge of the species occurrence and distribution is still not exhaustive.

Albania, located at the crossroads between the Adriatic and the northeastern Ionian Sea, has a coastline of approximately 480 km [16], where marine biodiversity is only partially described despite the significant role of marine ecosystems [13]. Until 2010, there were no marine protected areas (MPAs). At that time, however, the coast around the Karaburun Peninsula and the close by Sazan Island were proclaimed marine national parks (IUCN category II), covering an area of 12438 ha and accounting for approximately 2% of territorial waters.

The Management Plan of Karaburun-Sazan MPA dates back to 2015. In 2017, it was joined by a specific law on protected areas, although the final zoning was completed only in 2022. Since then, the MPA has been divided into three zones with increasing levels of protection (the recreational zone, traditional use ad sustainable development zone, and core zone). Many impacting anthropogenic activities have been outlawed (e.g., commercial fishing) or regulated (e.g., sport fishing). The harvest of the date Lithophaga lithophaga, previously listed as a species of national concern in the Albanian Red List of Wild Flora and Fauna (2007), was banned in 2012 along the Albanian coast.

Marine research in Albania has a relatively recent history. During the last 20 years, there has been an increase in research efforts and the publication of papers on local marine habitats. Most past studies on benthic assemblages referred to soft-bottom communities and lagoon systems, although a substantial amount was also dedicated to hard bottoms (for detailed references, see Supplementary Materials). Moreover, the existing literature data are mainly focused on taxa such as macroalgae, molluscs, decapod crustaceans, and echinoderms [17–24], while several other benthic groups such as sponges, annelids, and bryozoans are poorly studied or completely unknown.

Most information on Albanian coralligenous formations comes from studies conducted within MPAs. Karaburun-Sazan National Marine Park has become a priority study area, where the same management plan focused on coralligenous habitats. The latter has already been identified as a conservation priority by the National Biodiversity Strategy...
and Action Plan [25], recognizing mapping and monitoring of coralligenous habitats as an international obligation [13,26–28]. Data regarding the presence, abundance, and distribution patterns of marine species and communities in the Karaburun–Sazan MPA are relatively limited [13,26,29–32]. At present, available data include remarkable seaweed checklists [29,33,34], a detailed study of the genus Cystoseira [35], an inventory of Posidonia oceanica meadows [36,37], and a general assessment of species diversity and communities [12].

The present research responds to the EU policies on the Mediterranean marine environment, which require member states to develop strategies (officially known as the Marine Strategy Framework Directive (MSFD)) to achieve a Good Environmental Status (GES). This policy is based on identifying environmental targets, performing an initial environmental assessment, establishing monitoring programs, and finally, implementing the necessary measures to restore marine habitats and promote sustainable use of marine ecosystems, including the creation of MPAs. The MSFD is currently considered an environmental pillar of EU marine policies, bringing together the needs of other directives on environmental matters (e.g., the Water Framework Directive, Habitat Directive, and Birds Directive). Already being active for several years, the MSFD now evaluates and validates the collected data, underlining the presence of various knowledge gaps. The strategy to overcome the current data fragmentation includes the promotion of activities that would increase basic scientific knowledge of the marine environment and its processes. Thus, identifying habitats of community interest in data-deficient areas represents an important scientific starting point for future monitoring programs that would aim at conserving marine habitats.

In this scenario, the present study aimed to increase the current knowledge of coralligenous habitats in Albania by providing a preliminary description of their spatial distribution and associated macrobenthic assemblages in the Karaburun-Sazan National Marine Park. To achieve these objectives, we analysed underwater images collected at four sites along the Karaburun Peninsula and identified the main macrobenthic species associated with coralligenous bottoms. Considering that the structure, taxonomic composition, and environmental determinants of coralligenous communities are still little known along the Albanian coast, we hypothesized that (1) the species composition varies according to the geographical positions of the sites, thus reflecting strategies aimed at satisfying the biological needs of species and coping with environmental stressors, and (2) the taxonomic compositions of these communities vary with the depth.

2. Materials and Methods

The study area was located along the Albanian coast within the National Marine Park of Karaburun-Sazan. Karaburun Peninsula covers 62 km², encompassing the central part of the Albanian coast, separating the Adriatic from the Ionian coast of Albania, and facing the port of Vlora. The Karaburun Peninsula is formed by the Sazan zone, which is steep and faces eastward, and the verging promontory of the Apulian platform. This zone is an area of nondeposition from the Paleocene to the Lower Miocene. The area encompasses two geomorphological units: terrigenous formations, which can be heavily eroded, and carbonate rocks (limestone and limestone-dolomite with rudists or globotruncan of the Upper Cretaceous age) [38].

The entire peninsula faces the sea with steep and inaccessible cliffs. The western shore is tall and fragmented into many crevices, caves, gaps, and deep canyons that rarely end with gravel or sand pocket beaches. Access to several coastal parts, especially on the western side, is difficult due to the cliffs. The east coast, in contrast, is less fragmented and more accessible. The Cape of Gjuhezes (Këpë I Gjuhëzës) at the northwestern tip of the peninsula is the westernmost point of Albania. Detailed information on the hydrological regime of the study area can be found in [25], while the geomorphological characteristics are detailed in [39].
The present research was carried out in two depth ranges (15–20 m and 30–35 m) and at four areas along the Karaburun Peninsula, where preliminary surveys indicated the occurrence of coralligenous bioconstructions. The investigated areas were as follows: Zhapovel Bay (ZH), the Cape of Dhim Kushta (DH), Haxhi Ali Cave (HA), and the Cape of Gjuhezes (WE) (Figure 1). ZH is the only site not included in the MPA.

Figure 1. Map of Karaburun Peninsula with extension of the Karaburun-Sazan Marine Protected Area and the locations of the four sites: ZH = Zhapovel Bay, DH = Cape of Dhim Kushta, HA = Haxhi Ali Cave, and WE = Cape of Gjuhezes.

2.1. Macrobenthic Assemblages and Coralligenous Characterization

A macro-characterization of the sites was performed through video analysis in the framework of many initiatives sponsored by AISC Tirana and UNDP Albania to carry out the project “Improvement, covering and effective management of protected marine and coastal areas” to ensure the long-term protection of Albanian coastal and marine biodiversity in a sustainable manner. In the autumn of 2016, at each site, professional divers equipped with high-definition video cameras (SONY XDCAM full HD) carried out video transects from the surface to the base of the bioconstructions. Following the methodology proposed in “Module 7-reef habitat”, a reference for the “Monitoring program for Marine Strategy Directive (Art. 11, Legislative Decree 190/2010)”, a series of descriptors was measured during the dives to describe the biocenoses, such as the bathymetric range, sedimentation, inclination, substrate nature (Table 1), and the presence of anthropogenic disturbances (anchoring, lost fishing gears, date mussel harvesting, etc.).
Table 1. Parameters considered for the habitat characterization, with relative definitions.

| Parameter      | Definition                                                                 | Value          |
|----------------|-----------------------------------------------------------------------------|----------------|
| Epibiosis      | Extent of the phenomenon of epibiosis on single colonies or individuals as percentage of affected surface | Low: <25%      |
|                |                                                                             | Medium: 25–50% |
|                |                                                                             | High: >50%     |
| Necrosis       | Extent of the necrosis phenomenon on single colonies or individuals as percentage of affected surface | Low: <25%      |
|                |                                                                             |Medium: 25–50%  |
|                |                                                                             | High: >50%     |
| Sedimentation  | Qualitative estimation of the sedimentary covering                          | Low: <30%      |
|                |                                                                             | Medium: 30–60% |
|                |                                                                             | High: >60%     |
| Inclination    | Substrate slope                                                             | Horizontal: <30°|
|                |                                                                             | Inclined: 30–80°|
|                |                                                                             | Vertical: >80° |
| Substrate nature | General characterization of the substrate                                   | Biogenic boulders|
|                |                                                                             | Rocky cliff    |
|                |                                                                             | Blocks         |

To characterize macrobenthic assemblages, during the same sampling campaign, the professional divers recorded additional underwater videos. These were made along a 100-m transect within 50-cm visual fields at the same study sites and in two bathymetric ranges. At each site and bathymetry, 10 video frames (50 × 50 cm) were taken randomly for a total of 80 images. The frames were analyzed to identify taxa at the lowest possible taxonomic level. PhotoQuad software [40] was used to estimate the percentage of sessile species covering. Frequency values were calculated for each species as a percentage of presence for all video frames. Due to their indistinguishable external morphology, some species were grouped into operational taxonomic units (OTUs), such as “black horny sponges” (BHS), including *Ircinia variabilis* (Schmidt, 1862), *Sarcotragus spinosulus* Schmidt, 1862, *S. foetidus* Schmidt, 1862, and the “encrusting orange sponges” (EOS) *Crambe crambe* (Schmidt, 1862) and *Spirastrella cunctatrix* Schmidt, 1868. The use of OTUs as morphospecies is considered an effective method for determining distribution patterns in benthic invertebrates [41], particularly in marine sponges [42].

Furthermore, the percentage of epibiosis and necrosis of macrozoobenthic structured species was estimated (Table 1).

2.2. Statistical Analysis

Multivariate dispersion, based on the Bray–Curtis similarity measure of the covering data of each taxon, was used to test the null hypothesis, according to which composition models of macrobenthic species would remain invariable among geographic locations (sites) and depths (shallow vs. deep samples).

Multivariate analysis on the matrix of species’ covering values was performed to test for differences in the taxonomic composition of coralligenous assemblages at each site. All experimental data were computed using PERMANOVA in an approach similar to parametric ANOVA. Univariate PERMANOVA tests were run on Bray–Curtis similarity matrices with 9999 permutations. Site (four levels) and depth (two levels) factors were used to detect differences in species composition. In the case of insufficient permutations for PERMANOVA analysis, the reference p was obtained using the permutation simulation test (MONTECARLO test). The pairwise test was applied to discover statistically significant differences in each pair of factor levels based on the value of the PERMANOVA and MONTECARLO tests (data square root transformed).

Variance partitioning methods based on redundancy analysis (RDA) were used to quantify the contributions of the depth and position (as a proxy of sites) on macrobenthic
assemblages. The similarity percentage (SIMPER) analysis, using a cut-off of 90% cumulative dissimilarity, was performed to assess the taxa that were primarily responsible for the observed differences [43]. The mean values of species richness and macrobenthic percentage covering were also calculated and graphed over time. PERMANOVA and SIMPER analyses were conducted using PRIMER v6+ PERMANOVA software [44].

3. Results

3.1. Habitat Characterization

The analysis of video transects permitted obtaining a general overview of each study site. Overall, bioconstructions developed on vertical cliffs or sub-horizontal soft bottoms in the bathymetric range between approximately 15 and 40 m.

At Zhapovel Bay (ZH), coralligenous concretions started at 15 m and developed as large outcrops that were irregularly scattered and gradually sloped to a sub-horizontal sandy bottom at approximately 30 m in depth. The shallow portions (from the surface to approximately 5 m deep), heavily threatened by the destructive fishery of the European date Lithophaga lithophaga (Linnaeus, 1758) (Figure 2a), were represented by bare grounds. Elements of anthropogenic origin, such as ropes and fishing lines, were recorded on the deeper bottoms. In the basal portion, bioconstructions appeared intermittently in the form of scattered blocks with a few cavities.

Coralligenous formations at the Cape of Dhim Kushta (DH) developed from 15 to 30 m deep and consisted of rocky outcrops distributed over a gently sloping sandy bottom. These outcrops rose from a flat, sub-horizontal surface and showed a high sedimentation rate. A coralligenous was also present on a rocky cliff rising steeply from the sandy bottom, where sedimentation was comparatively lower. The outcrops were irregular in shape and rich in crevices and cavities, thus forming complex and heterogeneous habitats. Some objects of anthropogenic origin, such as ropes, were recorded. In shallower areas, traces of L. lithophaga fishery were also observed.

At Haxhi Ali Cave (HA), coralligenous formations started at 15 m in depth on vertical rocky rims which were relatively poor in cavities and holes in their upper part and had low sedimentation. As the vertical wall pushed deeper, at approximately 40 m in depth, there was an increase in sedimentation as well as in the number of cavities and habitat complexity. Subsequently, the slope appeared smoothed out, and the whole bioconstruction assumed a sub-horizontal aspect. There was no evidence of anthropogenic damages.

At the Cape of Gjuhezes (WE), coralligenous bioconstruction occurred between 15 and 40 m in depth on inclined rocky substrate composed of basal portions of vertical walls. The outcrops were complex and had many cavities and low sedimentation. In addition to the vertical growth, there were large outcrops widely extending along the ground with a slight horizontal slope. Physical damage from anchoring was observed in the deeper parts.
of the bioconstruction. *Cystoseira* spp. occupied large areas in the shallower portions, while we also recorded the invasive species *Caulerpa cylindracea* Sonder, 1845 (Figure 2b).

### 3.2. Macrobian Assemblage

A total of 61 macrobenthic taxa belonging to 12 phyla were detected, where 52 were identified at the species level (Table 2). Overall, algae had the highest covering value (49%) and included Rhodophyta (3 taxa, 31%), Ochrophyta (3 taxa, 1%), and Chlorophyta (6 taxa, 16%). Among sessile zoobenthos, sponges were the most representative group (30 taxa) with 24% substrate covering, followed by hydrozoans (6%), scleractinians (4%), and bryozoans (2%). Annelids and ascidians (four taxa in total and almost 1% of substrate covering) constituted the remaining animal fraction (Figure 3). Across the entire checklist, only one species was recognized as invasive, namely the green alga *Caulerpa cylindracea*, which was found at two out of four sites, with covering values varying between 0.5% (DH) and 11% (WE).

![Figure 3. Percentage of covering values (mean ± SD) of the taxa recorded during the study.](image)

| Phylum          | Class              | Species                                      | ZH | DH | HA | WE |
|-----------------|--------------------|----------------------------------------------|----|----|----|----|
| Orophyta        | Phaeophyceae       | *Zanardinia typus* (Nardo) P.C.Silva, 2000   |    |    | *  | *  |
|                 |                    | *Padina pavonica* (Linnaeus) Thivy, 1960     |    | *  |    |    |
|                 |                    | *Cystoseira spp.* C.Agardh, 1820              |    |    |    | *  |
| Chlorophyta     | Ulvophyceae        | *Caulerpa cylindracea* Sonder, 1845          |    | *  |    |    |
|                 |                    | *Codium bursa* (Olivi) C.Agardh, 1817        |    | *  |    |    |
|                 |                    | *Halimeda tuna* (J.Ellis & Solander) J.V.Lamouroux, 1816 |    |    | *  |    |
| Pyramimonadophyc|                    | *Flabbellia petiolata* (Turra) Nizamuddin, 1987 |    |    |    | *  |
| Rhodophyta      | Florideophyceae    | *Peyssonnelia rubra* (Greville) J.Agardh, 1851 |    | *  |    | *  |
|                 |                    | *Peyssonnelia squamaria* (S.G.Gmelin) Decaisne ex J.Agardh, 1842 |    | *  |    | *  |
| Porifera        | Calcarea           | *Clathria clathrus* (Schmidt, 1864)          |    |    |    |    |
|                 |                    | *Petrobiona massiliana* Vacelet & Lévi, 1958 |    |    | *  |    |
|                 | Homoscleromorpha   | *Oscarella lobularis* (Schmidt, 1862)        |    |    |    | *  |

Table 2. Checklist of the benthic taxa recorded at each site (* = presence of species).
| Family                  | Species                                                                 | Authors         |
|------------------------|-------------------------------------------------------------------------|-----------------|
| Demospongiae           | Acanthella acuta Schmidt, 1862                                          | *               |
|                        | Agelas oroides (Schmidt, 1864)                                          | *               |
|                        | Aplysina cavernicola (Vacelet, 1959)                                    | *               |
|                        | Axinella cannabina (Esper, 1794)                                        | *               |
|                        | Axinella damicornis (Esper, 1794)                                       | *               |
|                        | Axinella polypoideas Schmidt, 1862                                      | *               |
|                        | Axinella verrucosa (Esper, 1794)                                        | *               |
|                        | Chondrosia reniformis Nardo, 1847                                        | *               |
|                        | Cliona copiosa (Sarà, 1959)                                             | *               |
|                        | Cliona schmidtii (Ridley, 1881)                                         | *               |
|                        | Crambe crambe (Schmidt, 1862)                                           | *               |
|                        | Dendroxea lenis (Topsent, 1892)                                         | *               |
|                        | Dysidea avara (Schmidt, 1862)                                           | *               |
|                        | Haliclona (Halichoclona) fuloa (Topsent, 1893)                          | *               |
|                        | Hexadella racovitzai Topsent, 1896                                       | *               |
|                        | Ircinia variabilis (Schmidt, 1862)                                      | *               |
|                        | Merlia normani Kirkpatrick, 1908                                        | *               |
|                        | Mycale (Mycale) massa (Schmidt, 1862)                                   | *               |
|                        | Petrosia (Petrosia) ficiformis (Puiret, 1899)                           | *               |
|                        | Phorbas tenacior (Topsent, 1925)                                        | *               |
|                        | Sarcotragus foetidus Schmidt, 1862                                      | *               |
|                        | Sarcotragus spinosulus Schmidt, 1862                                    | *               |
|                        | Scalarispongia scalaris (Schmidt, 1862)                                 | *               |
|                        | Haliclonia sp.                                                           |                |
|                        | Cliona schmidtii (Ridley, 1881)                                         | *               |
|                        | Crambe crambe (Schmidt, 1862)                                           | *               |
|                        | Dendroxea lenis (Topsent, 1892)                                         | *               |
|                        | Dysidea avara (Schmidt, 1862)                                           | *               |
|                        | Haliclona (Halichoclona) fuloa (Topsent, 1893)                          | *               |
|                        | Mycale (Mycale) massa (Schmidt, 1862)                                   | *               |
|                        | Petrosia (Petrosia) ficiformis (Puiret, 1899)                           | *               |
|                        | Phorbas tenacior (Topsent, 1925)                                        | *               |
|                        | Sarcotragus foetidus Schmidt, 1862                                      | *               |
|                        | Sarcotragus spinosulus Schmidt, 1862                                    | *               |
|                        | Scalarispongia scalaris (Schmidt, 1862)                                 | *               |
|                        | Spirastrellidae ind.                                                    | *               |
|                        | Spongia lamella (Schulze, 1879)                                         | *               |
|                        | Spongia (Spongia) officinalis Linnaeus, 1759                             | *               |
| Hydrozoa               | Hydrozoa ind.                                                           | *               |
|                        | Caryophyllia sp.                                                        |                |
| Cnidaria               | Anthozoa                                                                |                |
|                        | Cladospsamnia rolandi Lacaze-Duthiers, 1897                             | *               |
|                        | Leptopsamnia pruvoti Lacaze-Duthiers, 1897                              | *               |
|                        | Madracis pharensis (Heller, 1868)                                       | *               |
|                        | Flabellina affinis (Gmelin, 1791)                                       | *               |
|                        | Pelodoris atrumaticulata Bergh, 1880                                    | *               |
| Mollusca               | Nudibranchia                                                            |                |
|                        | Filograna implexa Berkeley, 1835                                        | *               |
| Annelida               | Polychaeta                                                              |                |
|                        | Sabella spallanzanii (Gmelin, 1791)                                     | *               |
|                        | Hermodice carunculata (Pallas, 1766)                                    | *               |
| Bryozoa                | Stenolaemata                                                            |                |
|                        | Frondipora verrucosa (Lamouroux, 1821)                                  | *               |
|                        | Myriapora truncata (Pallas, 1766)                                       | *               |
|                        | Pentapora fascialis (Pallas, 1766)                                      | *               |
|                        | Schizomavella spp.                                                      | *               |
| Arthropoda             | Malacostraca                                                            |                |
|                        | Palinurus elephas (Fabricius, 1787)                                     | *               |
|                        | Echinaster (Echinaster) sepositus (Retzius, 1783)                        | *               |
|                        | Hacelia attenuata Gray, 1840                                            | *               |
| Echinodermata          | Polychaeta                                                              |                |
|                        | Sphaerechinus granularis (Lamarck, 1816)                                | *               |
|                        | Centrostephanus longispinus (Philippi, 1845)                            | *               |
| Chordata               | Ascidiacea                                                              |                |
|                        | Halocynthia papillosa (Linnaeus, 1767)                                  | *               |
The detailed distribution of macrobenthic taxa at each site, referring to both deep and shallow bioconstruction portions, is shown in Figure 4. The number of species at each site varied between 31 (WE) and 35 (HA).

Figure 4. Percentage of covering values (mean ± SD) of the main epibenthic taxa at each study site. ZH = Zhapovel Bay, DH = Cape of Dhim Kushta, HA = Haxhi Ali Cave, and WE = Cape of Gjuhezes.
At Zhapovel Bay (ZH, Figures 4 and 5a,b; 22 taxa found at shallow depths and 20 in the deep bathymetric range), red algae showed a covering value of 28 ± 3.7%. With a total frequency of 85%, this taxon was mainly represented by ECR in both the shallow and deep portions of the coralligenous formation. The presence of filamentous turf-forming green algae (hereafter referred to as turf) was also noteworthy, despite having lower covering value (11 ± 2.2%), and they mainly occurred in shallow bathymetric ranges. Within the invertebrate community, sponges were well represented at both depths, with an average covering of 25.2 ± 5.6%. Agelas oroides was detected in 65% of the frames. Other common sponge species were Spongilla (Spongilla officinalis) (3.3 ± 1%) and BHS (65% in frequency and 8% in covering values). Many structure-forming specimens of Axinella cannabina, A. polyoides, branched and arborescent Ircinia variabilis, and large horny sponges gave a marked three-dimensional appearance on the surface. The occurrence of large specimens of Chiona copiosa (sensu Sarà, 1959) in both the shallow and deep portions should also be highlighted due to their important role in bio-erasive processes. Hydrooids were frequent (70%), albeit with low covering values (4 ± 1%). Furthermore, structuring species showed a low level of epibiosis and necrosis but an overall presence of fine sediments over their surfaces.

In the Cape of Dhim Kushita (DH, Figures 4 and 5c,d; 16 taxa at shallow depths and 19 in the deep bathymetric range), red algae were the dominant taxon (27 ± 4.5% in covering). They were much more frequent in the deep portions of the bioconstructions (80% in frequency and 39 ± 4.5% in covering) and were mainly represented by Peyssonnelia rubra (80% in frequency and 18 ± 3.2% in covering value). Among invertebrates, sponges were the most abundant taxon, with similar covering values for both the deep and shallow bathymetric ranges (29% and 27%, respectively). They were mainly represented by A. oroides, which was more frequent in the deepest part of the coralligenous concretion (6.6 ± 1.5% in covering), and although less frequent, C. copiosa with an 8 ± 3% covering value. Phorbas tenacior (5 ± 2%) and EOS covered vast substrate portions. The bioconstruction was also extensively colonized by erect hydrozoans, which were present in 95% of the images and accounted for a mean of 16 ± 3.4 of covering. A remarkable epibiosis was observed for a few structuring species (Sarcotragus spinosulus) but without appreciable levels of necrosis.

At Haxhi Ali Cave (HA, Figures 4 and 5e,f; 20 taxa at shallow depths and 30 taxa in the deep bathymetric range), Rhodophyta was the dominant taxon (mean covering values of 42 ± 4.7%) for both the shallow and deep substrates, although it was more abundant in the deeper bathymetric range (43% covering). In the shallow portions, the presence of Chlorophyta Palmophyllum crassum was noteworthy, as this species was detected in 95% of the video frames, albeit with moderate covering values (13 ± 3.3%). Porifera accounted for 18 ± 2.6% of the benthic assemblage. Together with EOS, A. oroides was the most frequent species in the deepest bathymetric range (80%). A few specimens of the structural species Sarcotragus foetidus were also detected. Among the taxa with carbonate skeletons, there was a notable presence of the bryozoans Myriapora truncata and Pentapora fascialis (both occurring at a frequency of 57%) and scleractinians of the Leptopsammia/Cladopsammia complex (75% frequency), and they were widely distributed across the exposed substrate portion at greater depths. Madracis pharensis formed an additional 3D epibenthic substrate at some points, thus acting as a structuring species and adding a distinctive feature to the seascape. Epibiosis phenomena and tissue necrosis were negligible.

In the Cape of Gjuhezes (WE, Figures 4 and 5 g,h; 13 taxa found at shallow depths and 16 in the deep bathymetric range), the macrobenthic community at this site was characterized by algae, with green algae being the dominant taxon (mean covering values of 35 ± %) in both bathymetric ranges, though they were more frequent at shallower depths. They were mainly represented by P. crassum, identified in 100% of the video frames. Other recurrent taxa were Flabellia petiolata and algal turf (6 ± 1% average covering values). By contrast, red algae were more abundant in the deeper portions (29 ± 4%). Among them, P. rubra and ECR covered 27 ± 3.3% of the substrate and were very frequent (90% and 80%, respectively). Sponges showed a much lower covering value (10 ± 3%), being most
abundant in the deep portions ($7 \pm 3\%$). They were mainly represented by *A. oroides* and species of the EOS group. Epibiosis phenomena and tissue necrosis in the observed macrobenthic species were negligible.

**Figure 5.** Images of benthic assemblages from the coralligenous formations in the study areas: (a,b) Zhapovel Bay (ZH), (c,d) Cape of Dhim Kushta (DH), (e,f) Haxhi Ali Cave (HA), and (g,h) Cape of Gjuhezes (WE). The most conspicuous species present are marked as follows: 1. *Axinella cannabina*, 2. *A. polypoides*, 3. *Agelas oroides*, 4. *Sarcotragus foetidus*, 5. algal turf, 6. Encrusting Coralline Rodophyta (ECR), 7. *Chondrosia reniformis*, 8. *Peyssonnelia* sp., 9. *Cliona capiosa*, 10. *Pentapora fascialis*, 11. *Palmophyllum crassum*, 12. *Myriapora truncata*, 13. *Halocynthia papillosa*, 14. *Crambe crambe*, 15. *Phorbas tenacior*, 16. undetermined Spirastrellidae, and 17. *Hacelia attenuata*. 
3.3. Spatial Differences in Community Composition

The structures of the coralligenous assemblages differed at the spatial scale and between depths. The PERMANOVA analysis (Table 3) evidenced highly significant differences for both factors (site and depth) and their interaction. Specifically, the pairwise test conducted on site/depth interaction for each depth level revealed differences in almost all areas at the deepest levels. Except for DH and HA, where no differences were noted, all interactions showed significant differences in more superficial areas. Such assemblage patterns were well represented by the RDA plot, based on the covering percentages of all sessile taxa (Figure 6). This analysis highlighted differences in the structural evolutions of macrobenthic communities from the outermost (WE) to the innermost (ZH) sites and within them between shallow and deep bathymetric ranges.

Table 3. Permutational multivariate analysis of variance (PERMANOVA) performed on the dataset. Bray–Curtis resemblance matrix based on percentage of covering. Permutation N: 9999.

| Source          | Df | MS    | Pseudo-F | P(perm) |
|-----------------|----|-------|----------|---------|
| Site            | 3  | 16188 | 15.762   | 0.0001  |
| Depth           | 1  | 4135.8| 4.0269   | 0.0002  |
| Site × Depth    | 3  | 4707.5| 4.5836   | 0.0001  |
| Res             | 72 | 1027  |          |         |
| Total           | 79 |       |          |         |

Pairwise test (site × depth):
for Depth 15–20: ZH ≠ WE ≠ DH = HA
for Depth 25–30: ZH ≠ WE ≠ DH = HA

Figure 6. Redundancy analysis (RDA) plot showing the relationship between coralligenous bioconstructions based on the covering values of the associated macrobenthic taxa and environmental variables (depth and site). Sets of different colors include samples with different similarity levels. ZH = Zhapovel Bay, DH = Cape of Dhim Kusha, HA = Haxhi Ali Cave, WE = Cape of Gjuhezes, S = shallow replicates, and D = deep replicates. R²: 0.1013, and p (Perm): 0.001.

The SIMPER analysis (Table 4), based on a 90% cut-off of structural biodiversity, showed the taxa that contributed most as discriminant components between sites and depths.
Table 4. Similarity percentage (SIMPER) analysis with a 90% cut-off criterion for species covering.

| Group ZH |         |         |         |        |
|----------|---------|---------|---------|--------|
| Deep     |         |         |         |        |
| Average similarity: 36.54
| Species  | Av. Abund | Av. Sim | Sim/SD  | Contrib% | Cum%    |
|----------|------------|---------|---------|----------|---------|
| Peyssonella sp. | 31.95     | 16.88   | 0.86    | 46.18    | 46.18   |
| Algal turf | 17.79     | 7.54    | 0.80    | 20.63    | 66.82   |
| OTU EOS   | 5.27      | 2.61    | 0.64    | 7.14     | 73.96   |
| ECR       | 4.61      | 1.71    | 0.42    | 4.69     | 78.64   |
| Agelas oroides | 2.77   | 1.45    | 0.69    | 3.96     | 82.61   |
| OTU BHS   | 8.51      | 1.44    | 0.43    | 3.95     | 86.55   |
| Spongia (Spongia) officinalis | 5.28 | 1.37 | 0.37 | 3.75 | 90.31 |
| Shallow   |         |         |         |        |
| Average similarity: 52.53
| Species  | Av. Abund | Av. Sim | Sim/SD  | Contrib% | Cum%    |
|----------|------------|---------|---------|----------|---------|
| Peyssonella sp. | 42.03     | 19.69   | 2.43    | 37.48    | 37.48   |
| Algal turf | 26.93     | 8.97    | 1.20    | 17.07    | 54.55   |
| OTU BHS   | 30.14     | 6.64    | 0.95    | 12.63    | 67.18   |
| ECR       | 19.83     | 4.26    | 1.95    | 8.11     | 75.29   |
| Agelas oroides | 12.46  | 4.22    | 2.17    | 8.04     | 83.33   |
| Hydrozoa ind. | 11.06     | 2.70    | 1.42    | 5.14     | 88.47   |
| Cliona viridis | 8.95 | 1.77    | 0.62    | 3.38     | 91.85   |

| Group DH |         |         |         |        |
|----------|---------|---------|---------|--------|
| Deep     |         |         |         |        |
| Average similarity: 53.58
| Species  | Av. Abund | Av. Sim | Sim/SD  | Contrib% | Cum%    |
|----------|------------|---------|---------|----------|---------|
| ECR       | 4.91      | 10.48   | 2.97    | 19.56    | 19.56   |
| Hydrozoa ind. | 5.39 | 9.55    | 1.63    | 17.83    | 37.39   |
| Peyssonella sp. | 6.17 | 9.48   | 2.96    | 17.70    | 55.08   |
| Agelas oroides | 3.22 | 4.68    | 2.16    | 8.74     | 63.82   |
| OTU EOS   | 15.08     | 2.31    | 0.84    | 5.14     | 81.81   |
| Cliona viridis | 21.72 | 2.16    | 0.37    | 4.82     | 86.63   |
| OTU BHS   | 9.89      | 1.62    | 0.51    | 3.06     | 90.23   |
| Shallow   |         |         |         |        |
| Average similarity: 63.85
| Species  | Av. Abund | Av. Sim | Sim/SD  | Contrib% | Cum%    |
|----------|------------|---------|---------|----------|---------|
| Peyssonella sp. | 37.94 | 23.57   | 7.59    | 36.92    | 36.92   |
| Hydrozoa ind. | 26.28 | 13.88   | 4.04    | 21.73    | 58.65   |
| ECR       | 17.60     | 9.06    | 3.89    | 14.20    | 72.85   |
| Agelas oroides | 11.99 | 3.57    | 0.72    | 5.60     | 78.45   |
| Algal turf | 8.69   | 3.00    | 0.52    | 4.70     | 83.15   |
| Palmophyllum crassum | 6.83   | 2.98    | 0.72    | 4.66     | 87.81   |
| OTU EOS   | 12.91     | 2.88    | 0.51    | 4.21     | 92.31   |

| Group HA |         |         |         |        |
|----------|---------|---------|---------|--------|
| Deep     |         |         |         |        |
| Average similarity: 51.62
| Species  | Av. Abund | Av. Sim | Sim/SD  | Contrib% | Cum%    |
|----------|------------|---------|---------|----------|---------|
| Palmophyllum crassum | 30.79 | 13.89   | 1.73    | 26.91    | 26.91   |
| OTU EOS   | 24.72     | 8.17    | 1.58    | 15.82    | 42.74   |
| Peyssonella sp. | 41.71 | 7.72    | 0.98    | 14.95    | 57.69   |
| Lepto/Cladopsammia complex | 16.33 | 5.58    | 1.86    | 10.81    | 68.50   |
| Species                   | Av. Abund | Av. Sim | Sim/SD | Contrib% | Cum%  |
|---------------------------|-----------|---------|--------|----------|-------|
| ECR                       | 19.20     | 4.81    | 1.04   | 9.32     | 77.82 |
| *Palmophyllum crassum*    | 30.79     | 13.89   | 1.73   | 26.91    | 26.91 |
| *Agelas oroides*          | 9.00      | 3.5     | 1.82   | 6.78     | 84.60 |
| Gelatinous red algae      | 10.22     | 2.39    | 0.64   | 4.64     | 89.24 |
| *Phorbas tenacior*        | 3.49      | 0.98    | 0.67   | 1.9      | 91.14 |

**Average similarity: 48.37**

**Shallow**

**Average similarity: 55.26**

| Species                   | Av. Abund | Av. Sim | Sim/SD | Contrib% | Cum%  |
|---------------------------|-----------|---------|--------|----------|-------|
| *Peyssonnelia* sp.        | 62.11     | 28.91   | 1.70   | 59.78    | 59.78 |
| *Palmophyllum crassum*    | 15.22     | 8.79    | 1.10   | 18.17    | 77.95 |
| *Hydrozoa* ind.           | 7.53      | 2.58    | 0.78   | 5.34     | 83.29 |
| ECR                       | 7.98      | 2.47    | 0.74   | 5.11     | 88.40 |
| *Agelas oroides*          | 8.73      | 1.57    | 0.54   | 3.24     | 91.63 |

| Group WE                  |           |         |        |          |       |
|---------------------------|-----------|---------|--------|----------|-------|
| **Deep**                  |           |         |        |          |       |
| Average similarity: 50.73  |           |         |        |          |       |

| Species                   | Av. Abund | Av. Sim | Sim/SD | Contrib% | Cum%  |
|---------------------------|-----------|---------|--------|----------|-------|
| *Palmophyllum crassum*    | 21.81     | 29.49   | 3.97   | 53.37    | 53.37 |
| *Peyssonnelia* sp.        | 11.13     | 11.57   | 1.70   | 20.93    | 74.30 |
| Gelatinous red algae      | 6.78      | 5.04    | 0.75   | 9.12     | 83.42 |
| ECR                       | 4.25      | 3.39    | 0.62   | 6.13     | 89.55 |
| Algal turf                | 4.29      | 2.76    | 0.90   | 5.00     | 94.55 |

| **Shallow**               |           |         |        |          |       |
| Average similarity: 50.73  |           |         |        |          |       |

| Species                   | Av. Abund | Av. Sim | Sim/SD | Contrib% | Cum%  |
|---------------------------|-----------|---------|--------|----------|-------|
| ECR                       | 17.59     | 13.64   | 1.85   | 26.88    | 26.88 |
| *Palmophyllum crassum*    | 12.93     | 10.82   | 1.12   | 21.33    | 48.21 |
| *Agelas oroides*          | 17.10     | 10.29   | 1.46   | 20.29    | 68.50 |
| *Peyssonnelia* sp.        | 13.40     | 8.54    | 0.94   | 16.83    | 85.33 |
| OTU EOS                   | 5.87      | 3.92    | 1.02   | 7.72     | 93.05 |

**4. Discussion**

The present pioneer study provides the first formal biodiversity dataset on the coral-igenous bioconstructions along the Karaburun-Sazan Peninsula in Albania. Coralligenous formations were distributed between 15 and 40 m in depth on rocky and biogenic substrates, emerging from vertical cliffs or sub-horizontal soft bottoms. This study improved our understanding of the Albanian coralligenous formations by describing associated macrobenthic assemblages. Over a total of 60 recorded taxa, 52 were identified at the species level, thus allowing an update of the checklist of macrofauna from coralligenous habitats of the Albanian coast with 34 new species [13,14,30,31,45], 16 of which belong to poriferans.

Our results highlighted the presence of healthy coralligenous bioconstructions below 15 m in depth, as evidenced by the occurrence of numerous specimens of erect and arborescent species, mainly poriferans, bryozoans, and polychaetes. The arborescent species contributed to the formation of a three-dimensional structure with heterogeneous and rich microhabitats. Since they are susceptible to mechanical damage, their presence implied that anchoring and fishing had a moderate impact on the bottom communities. In addition, the presence of commercially important sponges (e.g., *Spongia* spp.) suggested the absence of their direct harvesting. Lost fishing lines and ropes were present at the eastern sites ZH and DH, while WE showed isolated mechanical damage caused by anchoring. Considerable damage caused by date mussel fishery was recorded at three sites (ZH, DH, and WE) on photophilous substrates between 0 and 10 m in depth. However, the damage was less pronounced on the deeper bottoms and did not involve coralligenous formations.
It should be underlined that this research was conducted six years after MPA institution and 4 years after the ban on date mussel fishing by the Albanian government (Law no. 64/2012, Art. 16 and 37). Similarly, considerable damage caused by large-scale date mussel fishery was also recorded along the Apulian coasts, located a few tens of kilometers away on the western side of the Adriatic Sea [12,46].

The short time that elapsed between protection regime implementation and this research was not sufficient to establish a clear relationship between institution of MPAs and assessment of the local macrobenthic community. The latter rather represents a baseline for future monitoring surveys.

Regarding the occurrence of invasive alien species, we detected only Caulerpa cylindracea (at DH and WE), one of the most threatening invaders [47,48] which is included on the list of the 100 worst non-indigenous species of the Mediterranean [49] and the IUCN Blacklist of Invasive Species [50]. The presence of a single alien species is an element that should be considered, albeit with some caution. Corriero et al. [51] documented 28 alien species within coralligenous formations along Italian coasts, although the data cannot be directly compared due to different spatial and temporal observation scales. According to the invasion models proposed by Catford et al. [52], this pattern could be explained either by a higher resistance for coralligenous habitats in Albania, which could exert a greater biotic filter against invasions or by a lower propagule pressure in the area (decreased action of introduction vectors such as commercial ports or mariculture). The area could further benefit from the institution of MPAs, as the latter favors restoration and conservation of benthic communities, and by the reduction of commercial, touristic, and military development, that could also limit the arrival of new alien species.

Regarding the number of species recorded, all sites displayed relatively similar values (33 species for ZH and DH, 35 for HA, and 31 for WE) with differences between depth ranges. While at the most confined site (ZH), there was a higher species richness in the more superficial belt (15–20 m), the deep assemblages had a higher number of species at all other sites. This was particularly evident at HA, where the shallower assemblage showed approximately two thirds of the taxa present on deeper grounds. Regarding the structure of the macrobenthic communities, the four sites showed a certain heterogeneity, with differences concerning both geographical location (site) and depth. These differences could be attributed to species composition and relative species frequencies. The RDA analysis performed on the taxa covering values confirmed the relationship between the community structure and the investigated variables (depth and site). It displayed a separation between assemblages at eastern sites (DH and ZH) and those on the northern (HA) and western (WE) sides of the peninsula, even when considering the depth. The community structures at different sites and the number of species could be influenced by the geographical position, following a gradient from the inside to the outside of the bay, which is likely to reflect different sedimentological and hydrodynamic conditions [53]. Moreover, the most exposed sites (WE and HA) were more affected by wave action, especially on shallower bottoms, and this may explain the higher species richness on deeper substrates at almost all sites. In this regard, many authors [54,55] pointed out that different combinations of physiographic (bathymetry), physical (winds and currents), and oceanographic (temperature, salinity, and productivity) conditions influenced the patterns of species diversity and marine habitat heterogeneity in the Mediterranean. Wave exposure [56], together with sedimentation regimes, is known to affect benthic assemblages [57,58] and sponge assemblages in particular [56,59]. Indeed, there was a marked difference between exposed and unexposed sites.

A few taxa were common to all sites (n = 11, about 18% of the checklist), whereas one third of the taxa (n = 20) was recorded at only one site (exclusive taxa). The taxa distribution pattern was interesting, considering that all exclusive taxa at WE were algae (Zanardinia typus, Cystoseira spp., Codium bursa, and Flabellia petiolata), while at ZH, the eight exclusive species were sponges (see Table 2). This result seems to be in accordance with the species distribution recorded on Sardinian coralligenous bottoms, where the western sites...
were dominated by brown erect macroalgae benefiting from local conditions of upwelling [60]. WE is located on the western coasts of the Karaburun-Sazan Peninsula, where similar hydrodynamic conditions are likely to occur. Macroalgae might compete with sessile invertebrates, thus explaining the lower presence of the latter at this site.

Overall, among invertebrates, poriferans had the highest species richness (n = 30) and covering values, with the latter showing a regular decrease from 35% at ZH (the most confined site) to 10% at WE (less confined site). Coherently, with what was observed for the entire assemblage, sponges had a higher species richness on the deeper bottoms at all sites except WE, where the wave action affects shallower substrates more intensively. Sixteen recorded poriferans have already been reported for the Apulian coralligenous [61] a few kilometers apart from the coasts of Albania. The comparison has ecological validity linked to the dynamics of the exchange of currents (and transported material) between two shores of the Albanian coast. Bray et al. [62] showed that currents in the southern Adriatic generally carry particles from east to west, thus making it an area of high connectivity. Paterno et al. [63] also suggested that areas within the Adriatic-Ionian basin are potentially connected through a relatively persistent flow of propagules. Therefore, the communities present on the two opposite shores could be connected by a persistent gene flow.

In the Mediterranean Sea, the contribution of poriferans to sciaphilous bioconstructions takes on greater importance when proceeding from the west to the east. Recent studies [64] reported that epibenthic coralligenous assemblages follow a clear gradient across Mediterranean ecoregions, with the western basin mainly dominated by gorgonians and the eastern by massive sponges and ascidians. However, on a local scale, sponges and cnidarians characterize coralligenous bottoms in the central Tyrrenhenian Sea [65,66], and the former taxon results are dominant in the coralligenous from the near southeastern Italian coasts [61].

The Albanian coralligenous showed some peculiarities, since three sponge species recorded during the present study (Petrobiona massiliana, Hexadella racovitzai, and Merlia normani) were not included in the Apulian coralligenous biodiversity checklist [61], although H. racovitzai has been recently described within Apulian mesophotic biogenic reefs [7–9].

It is noteworthy that eight taxa recorded during this study (about 23% of the total species), namely the brown algae Cystoseira spp., the sponges Axinella cannabina, A. polyoides, Aplysina cavernicola, Spongia (Spongia) lamella, and S. (S.) officinalis, the crustacean Palinurus elephas, and the echinoderm Centrostephanus longispinus, are included in the international wildlife protection conventions (Barcelona and Bern Conventions, Habitat Directive). In particular, S. (S.) officinalis and S. (S.) lamella are two of the five Mediterranean commercial sponges overexploited in past few years [67,68] and are included in Annex III of both the Bern and Barcelona Conventions.

5. Conclusions

The results of the present study, albeit preliminary, revealed rich and diversified coralligenous bioconstructions along the Albanian coast. Along the investigated coasts, the collection of sea dates was intensive until a few years ago and left evident traces on hard substrates at low depths. However, at greater depths, on coralligenous substrates, the presence of invertebrates of conservation interest and rare species indicates a modest anthropogenic impact. Therefore, the need to protect coralligenous communities along this stretch of the Albanian coast appears evident.

The establishment of the Karaburun-Sazan MPA in 2010 can contribute to the conservation of this area. Although the effective MPA management plan (Albanian Ministry of the Environment, Order n. 750, 24 November 2015) was approved a few months before the start of the present study, activities such as port construction and maritime traffic have been regulated from then on, and aquaculture and military activities have been banned altogether, suggesting that the coralligenous habitat of the MPA is now properly preserved from direct human impacts. The importance of the protection regime imposed by
the presence of the MPA is of interest not only for Albanian coasts but also considering ecological dynamics on a larger scale.

In this context, preliminary data aimed at increasing knowledge on habitats subjected to protection regimes represent the first tool for preserving biodiversity within MPAs. This type of research should be improved in the near future with more in-depth investigations in order to permit an optimal characterization of the environments to be protected while also bearing in mind that direct and indirect anthropogenic impacts on marine environments will likely increase in the near future.

**Supplementary Materials:** The following supporting information can be downloaded at www.mdpi.com/xxxx/s1. Table S1: List of bibliographic resources on Albanian marine and lagoon biodiversity found during this research and not mentioned in the text.

**Author Contributions:** Conceptualization, G.C., G.G., and C.P.; methodology, G.G., M.M., T.L., L.L., and V.Z.; validation, S.B., L.L., M.Z., and V.Z.; formal analysis, G.G., C.L., and M.M.; resources, S.B., L.L., and V.Z.; writing—original draft preparation, G.G., C.C., and C.P.; writing—review and editing, G.G., S.B., T.L., C.L., M.M., and C.N.M.; supervision, G.C. and C.P. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was partially financed by AISC Tirana and UNDP Albania.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Acknowledgements:** The authors wish to thank Riccardo Cingillo for the support during the data acquisition activities and the three anonymous reviewers, whose suggestions contributed to improving the present paper.

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

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