

CORALLIGENOUS CLIFFS IN TUSCANY: DISTRIBUTION, EXTENSION OF THE HABITAT AND STRUCTURE OF ASSEMBLAGES

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Abstract – Coralligenous reefs are the main biogenic constructions of the Mediterranean Sea. The two main coralligenous morphologies are the coralligenous cliffs and platforms, the former developing in shallow waters (about 20-50 m) on vertical/subvertical rocky substrate and the latter built over horizontal substrates below 50 m depth also on detritic bottoms. The present study aims at assessing the distribution and extension of the coralligenous cliffs in Tuscany and describing the structure and the patterns of spatial variability. The mapping of seabed was obtained through Multibeam echosounder data coupled with video images recorded by using a Remote Operating Vehicle equipped with a high-resolution camera. Coralligenous cliffs were sampled by SCUBA divers in 11 sites (sectors of rocky coasts) following the STAR procedure. Coralligenous cliffs were present in all study sites, with a total length of about 62.5 km and a total surface of 0.47 km². The linear extension of the habitat may be estimated about the 20 % of Tuscany rocky coast. The assemblages of continental coasts segregated from those of islands and were mostly characterized by algal turf, encrusting sponges and *Corallium rubrum*. The southern islands (Giglio, Montecristo and Formiche) were separated from the others and mostly characterized by terete and flattened Rhodophyta, *Eunicella* spp., *Paramuricea clavata* and erect bryozoans. The other Island had high abundance of *Flabellia petiolata*, *Halimeda tuna* and massive sponges. Gorgona was separated from all other sites and showed a high abundance of *Peyssonnelia* spp.

Introduction

Coralligenous reefs are the main biogenic constructions of the Mediterranean Sea which are considered indicators of the ecological quality of coastal systems and of “seafloor integrity” by the Marine Strategy Framework Directive [4]. The two main coralligenous morphologies are the coralligenous cliffs and platforms, the former developing in shallow waters (about 20-50 m) on vertical/subvertical rocky substrate, and the latter built over horizontal substrates below 50 m depth also on detritic bottoms [4]. Both habitats are widely investigated; coralligenous cliffs are sampled mostly by SCUBA divers, while ROVs (Remotely Operated Vehicles) are usually utilised for coralligenous platforms [5, and references therein]. In most cases, mapping programs do not distinguish the two coralligenous habitats and cliffs, due to their development on vertical bottoms, are normally not considered or under-estimated. Consequently, information about the relative importance of the two habitats within the same geographic area lacking. The present study aims at

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assessing the distribution and extension of the coralligenous cliffs in Tuscany and describing the structure and the patterns of spatial variability.

Material and Methods

The mapping of seabed was obtained through Multibeam echosounder data coupled with video images recorded by using a Remote Operating Vehicle equipped with a high-resolution camera during different surveys between 2014 and 2020. The spatial extension of coralligenous cliffs and platforms was obtained from digital images of bottoms considering as coralligenous cliff the hard bottom included in a depth of 30-40 m and a slope of 60°-90°, and as coralligenous platform the hard bottom included in a depth 45-100 m and a slope of 10°-50°. Coralligenous cliffs were sampled by SCUBA divers in 11 sites (sectors of rocky costs, Fig. 1) following the STAR procedure [3]. In each site, two areas several kms apart were chosen. At each area, three plots of about 4 m² where randomly selected on a vertical rocky substrate at 35 m depth. In each plot, ten photographs of 0.2 m² areas were collected by a framed camera. The percentage cover of the main taxa/groups was assessed in each photo by manual contour technique using the ImageJ software [3]. Spatial differences in the structure of assemblages (presence and abundance of taxa/groups) were analyzed by permutational analysis of variance (Primer6 + PERMANOVA, [1]) on fourth root transformed Bray-Curtis resemblance matrix. A multi-factorial model was used with the factors Site (*Livorno, Argentario, Gorgona, Capraia, Elba nord, Elba est, Pianosa, Montecristo, Giglio, Giannutri* and *Formiche di Grosseto*) as fixed, Area (2 levels) as random and nested in Site, and Plot (3 levels) as random and nested in Area. An MDS (Multi Dimensional scaling) ordination was used to highlight the variability among sites and the taxa/groups mostly responsible of the spatial pattern.



Figure 1 – Study sites and distribution of coralligenous cliffs.

Results

PERMANOVA detected a significant variability at all examined spatial scales (Table 1). The assemblages of continental coasts segregated from those of islands and were mostly characterized by algal turf, erect sponges and *Corallium rubrum*. The southern islands (Giglio, Montecristo and Formiche) were separated from the others and mostly characterized by, *Eunicella* spp., *Paramuricea clavata* and erect bryozoans. The other Island had high abundance of *Halimeda tuna*. Gorgona was separated from all other sites and showed a high abundance of *Peyssonnelia* spp. and terete Rhodophyta (Fig. 2).

Coralligenous cliffs were present in all study sites, with a total length of about 62.5 km and a total surface of 0.47 km². The linear extension of the habitat may be estimated about the 20 % of Tuscany rocky coast (Fig. 3).

Table 1 – PERMANOVA on coralligenous cliff assemblages of Tuscany.

Source	df	MS	Pseudo-F	P(perm)
Site = S	12	46483	3.688	0.001
Area(S)	13	12602	18.539	0.001
Residual	754	679		

Pair-wise test: LIVO≠PIOM≠ARGE≠VADA=MELO≠PIAN= MONT
=GIGL=FORM=EL-ES=EL-NW≠CAPR≠GIAN≠GORG

df= degree of freedom; MS=mean sum of squares; Pseudo-F= F value by permutation;
P(perm)=p-value based on permutation

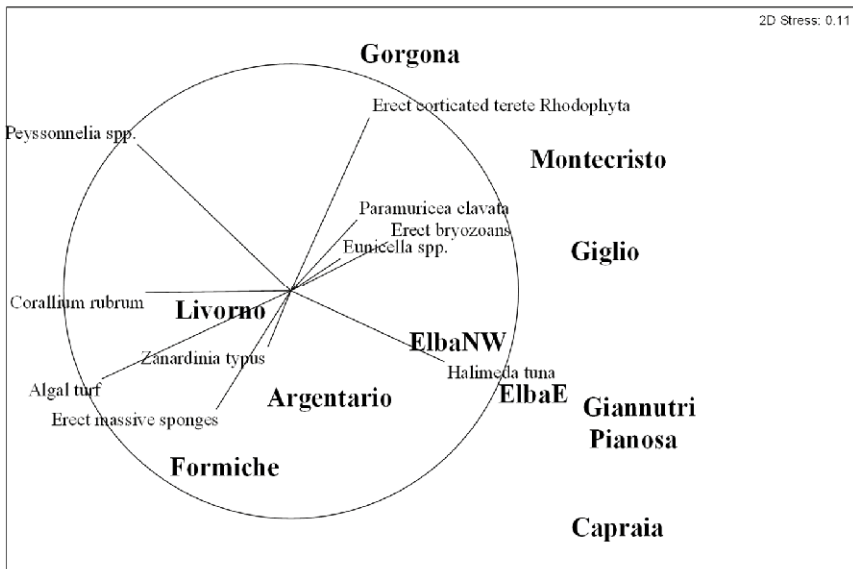


Figure 2 – MDS ordination on coralligenous cliff assemblages of Tuscany.

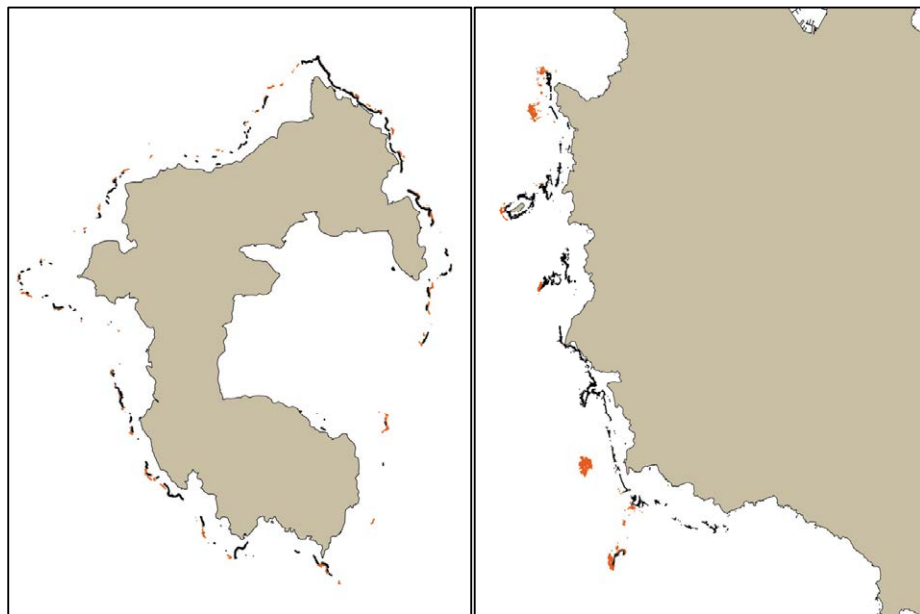


Figure 3 – Distribution of coralligenous cliffs (black) and platform (orange) at Giannutri (left) and Argentario (right).

Discussion

This study compares, for the first time, the surface of coralligenous cliffs and platforms highlighting the great importance, in term of extension and biodiversity, of coralligenous cliffs within the wide geographic area considered (Tuscany). Overall, the surface of coralligenous cliffs was about the 12 % of that of the Tuscany coralligenous reefs but values were highly variable. In fact, most coralligenous platforms are distributed around Meloria Shoals (more than 70 % of the whole habitat). In most of the other sites the spatial extension of coralligenous cliffs and platforms is similar and in some of them, such as Livorno, Capraia, Elba, Argentario and Giannutri, coralligenous cliffs are largest than coralligenous platforms. Thus, the approach used in the study highlighted that coralligenous cliffs represent a considerable part of circalittoral biogenic habitat, suggesting that its relevance could be higher than that normally emerges from seabed mapping.

Moreover, results confirmed the high level of biodiversity and spatial heterogeneity of coralligenous cliff assemblages already described in other Mediterranean areas. The assemblages mostly varied at large (among sites) and small (among samples) spatial scales, confirming a pattern already highlighted in previous studies [2]. The variability at small scale may be attributed to the patch distribution of assemblages mostly due to the high heterogeneity of biogenic substrate [2].

Conclusions

Coastal and continental shelf coralligenous reefs provide different ecosystem services and are subjected to different human related threats. These features combine to separate coastal coralligenous cliffs from other coralligenous habitats, such as platforms, banks and outcrops distributing on continental shelves. In this context, the assessment of their extension, structure and variability patterns plays a fundamental role from a conservation point of view. Thus, following the approach used in the present paper, coralligenous cliffs should be considered separately in monitoring programs, impact assessment studies and management plans

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