

## Seafloor integrity down the harbor waterfront: the coralligenous shoals off Vado Ligure (NW Mediterranean)

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In the last ten years, European Directives stressed the necessity to assess the ecological status of marine habitats by means of ecosystem or landscape indicators, rather than just species or chemical ones. In this paper, the seascape approach to characterise and assess the ecological quality of coralligenous rocky shoals of Vado Ligure (Savona, Italy) is introduced. This approach integrates biological, mesological and geomorphological information collected with a Rapid Visual Assessment technique (RVA). The RVA also optimised underwater operations in deep waters where coralligenous reefs usually develop and provided a sufficient amount of data collected by direct inspection. The seascape approach results are appropriate for the characterisation of the coralligenous shoals studied and for the assessment of their ecological quality. The quality of the assemblages was in general low, mainly due to high sedimentary stress; however, some exceptions showing a high ecological quality indicate that, with proper management tools, they would still have good potentialities of recovery.

**Keywords:** seascape; coralligenous; ecological quality status; Rapid Visual Assessment technique; Mediterranean Sea

### 1. Introduction

Intense urbanization is one of the major drivers replacing natural ecosystems with human-dominated landscapes, with obvious consequences on habitat structure, biodiversity and functioning [1]. The coastal zone is strongly urbanized today and about two-thirds of the Mediterranean coastline is characterised by harbours and ports [2]. Coastal ecosystems are among the most threatened worldwide, but a full understanding of the effects of extensive coastal development on marine environment is still far from being reached [3,4].

Assessment of the status of coastal waters is required by the European Water Framework Directive (WFD, 2000/60/EEC) through the selection of appropriate Biological Quality Elements (BQEs) [5] and with the support of hydromorphology and physico-chemical descriptors [6]. WFD attempts to achieve an ecosystem level assessment

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by evaluating separately selected ecosystem components. Similarly, the Marine Strategy Framework Directive (MSFD, 2008/56/EEC) underlines the necessity to assess the ecological status of marine habitats at ecosystem level rather than at species or chemical levels alone [7,8]. Landscape or, more properly, seascape approaches [9,10] integrate various levels of information from species identification to habitat structure characterisation, as requested by the MSFD, and have great potential to enhance our understanding and management of coastal environments [11].

One of the most important coastal habitats in the Mediterranean Sea is represented by the so-called “coralligenous” [12], an endemic underwater habitat [13] shaped by bioconstructors and characterised by high species richness, biomass and production. Its calcification rate, assessed around  $10^3 \text{ g CaCO}_3 \text{ m}^{-2} \text{ y}^{-1}$ , falls within the range of values calculated for tropical reefs [14]. It develops on rocky reefs and biodetritic bottoms from about 20 m down to 120 m depth, in relatively constant conditions of temperature, currents and salinity. Coralligenous reefs result from the dynamic equilibrium between bioconstruction (mainly by encrusting red algae, with an accessory contribution by serpulid polychaetes, bryozoans and scleractinian corals), and destruction processes (by borers and physical abrasion) [15], which create morphologically complex substrates where highly diverse benthic assemblages develop [16–19].

Despite the occurrence of many species with high ecological value (some of which are also legally protected, e.g. *Savalia savaglia*, *Spongia officinalis*, etc.), coralligenous reefs were not listed among the priority habitats defined by the EU Habitat Directive (92/43/EEC). This implies that the most important Mediterranean bioconstruction still remained without formal protection and it was not included within the list of Sites of Community Interest (SCIs). Few years after the adoption of the Habitat Directive, coralligenous reefs were listed among the habitats needing rigorous protection by the Protocol for special protected areas (SPA/BIO) of the Barcelona Convention for the conservation of Mediterranean biodiversity (1995) [20]. However, the concept of “rigorous protection” sounds somewhat vague and only recently, the “Action plan for the conservation of coralligenous and other calcareous concretions in the Mediterranean Sea” [13] encouraged the conservation of the coralligenous by the establishment of marine protected areas and emphasized the need for standardised programs for its monitoring. Coralligenous is threatened by direct human activities, such as trawling and illegal exploitation of protected species, and is also vulnerable to the indirect effects of climate change (e.g. positive thermal peaks). To date, however, neither national legislations to protect coralligenous reefs nor rigorous scientifically-based management and monitoring programs have yet been proposed [21].

Due to its large bathymetric distribution and the consequent sampling constraints, coralligenous was subjected to limited spatio-temporal studies, so that its geographical distribution and health status remain poorly known at regional level. The operational restrictions imposed by SCUBA diving [22] reduce the amount of collected data during each dive and increase the sampling effort. To optimise the diving time, photo-quadrats [23], frequency counts [22] and point intercept transects [24] have been proposed as efficient sampling techniques of benthic assemblages; however, most of them are not commonly employed on the coralligenous [but see 25].

Since the coralligenous is characterised by high heterogeneity, extreme patchiness and coexistence of several biotic assemblages, a seascape approach seems to be the most reasonable solution for its characterisation. This study had three distinct aims: 1) to obtain a first characterisation of the coralligenous shoals of Vado Ligure (Italy, NW

Mediterranean) employing a seascape approach, i.e. integrating the bionomic description of benthic assemblages [26] with geomorphologic and mesologic (physical) characterisation of the shoals; 2) to assess preliminarily their quality; 3) to propose a Rapid Visual Assessment technique (RVA) for optimising underwater surveys, inspired by the one described by Bianchi et al. [27] and mainly focused on seascape rather than on community aspects [28].

## 2. Material and methods

### 2.1. Study area and field activities

The study was carried out in April 2010 on the coralligenous shoals of Vado Ligure (Savona, Italy, NW Mediterranean), an area that is very close to an important commercial harbour (Figure 1). Pre-existing information collected by a multi-beam provided the preliminary morphology and the exact position of all coralligenous shoals. Five shoals (each composed by various rocky outcrops) were then chosen for sea-truthing. One to four surveys were performed in each shoal, according to its extent and morphological heterogeneity: surveys 1.1, 1.2, 1.3 were conducted in shoal 1; surveys 2.1, 2.2, 2.3, 2.4 in shoal 2; surveys 3.1, 3.2, 3.3, 3.4 in shoal 3; surveys 4.1, 4.2, 4.3, 4.4 in shoal 4 and survey 5.1 in shoal 5.

The geomorphologic characterisation of each shoal was obtained *in situ* by considering three main “morphotypes”: 1) high rocky outcrops (HR); 2) low rocky outcrops (< 1.5 m height) (LR); 3) landslide deposits (LD). For each survey, mesologic parameters, i.e. depth, slope of the substrate and elevation from the bottom, were measured.

As the coralligenous shows a stratified structure [29], bionomic characterisation in each survey was performed separately for three distinct layers: 1) upper layer, characterised by organisms with considerable (>10 cm) vertical growth (e.g. *Paramuricea clavata*, *Cystoseira zosteroides*); 2) intermediate layer, constituted by organisms with moderate (1 cm to 10 cm) vertical growth (e.g. *Reteporella grimaldii*, *Axinella damicornis*); 3) basal layer, constituted by encrusting or with limited (<1 cm) vertical growth organisms (e.g. *Lithophyllum incrustans*, turf forming algae). In the upper layer, the percent cover of each species was visually estimated over an area of about 2 m<sup>2</sup>, the maximum height of the tallest species was measured and the percentage of necrosis and/or epibiosis of organisms was estimated according to the method described by Harmelin [30]. For the intermediate layer a time-restricted [31] taxonomic list of the conspicuous species was compiled in two minutes over the same area of 2 m<sup>2</sup>. Time restricted sampling consists of listing all the species that can be found within a fixed time range. In our case, two minutes were chosen since preliminary inspections showed that a longer search did not increase significantly the number of species detected. In the basal layer, five non-taxonomic descriptors (NTDs) were identified, namely: encrusting calcified rhodophyta (ECR), non-calcified encrusting algae (NCEA), encrusting animals (EA), turf-forming algae (TURF), sediment (SED). The percent cover of each NTD was estimated. As suggested by Hiscock [32 and references therein], a semi-quantitative assessment of boring species marks (e.g. clionid papillae and bivalve holes) was also performed through the assignation of three classes of abundance: (1) common, when more than 1 mark occurred in 0.5 m<sup>2</sup>; (2) occasional, when marks were less than 1 per m<sup>2</sup>; (3) absent, when marks did not occur. The thickness and consistency of calcareous concretion was measured in millimetres with a handheld penetrometer [27].

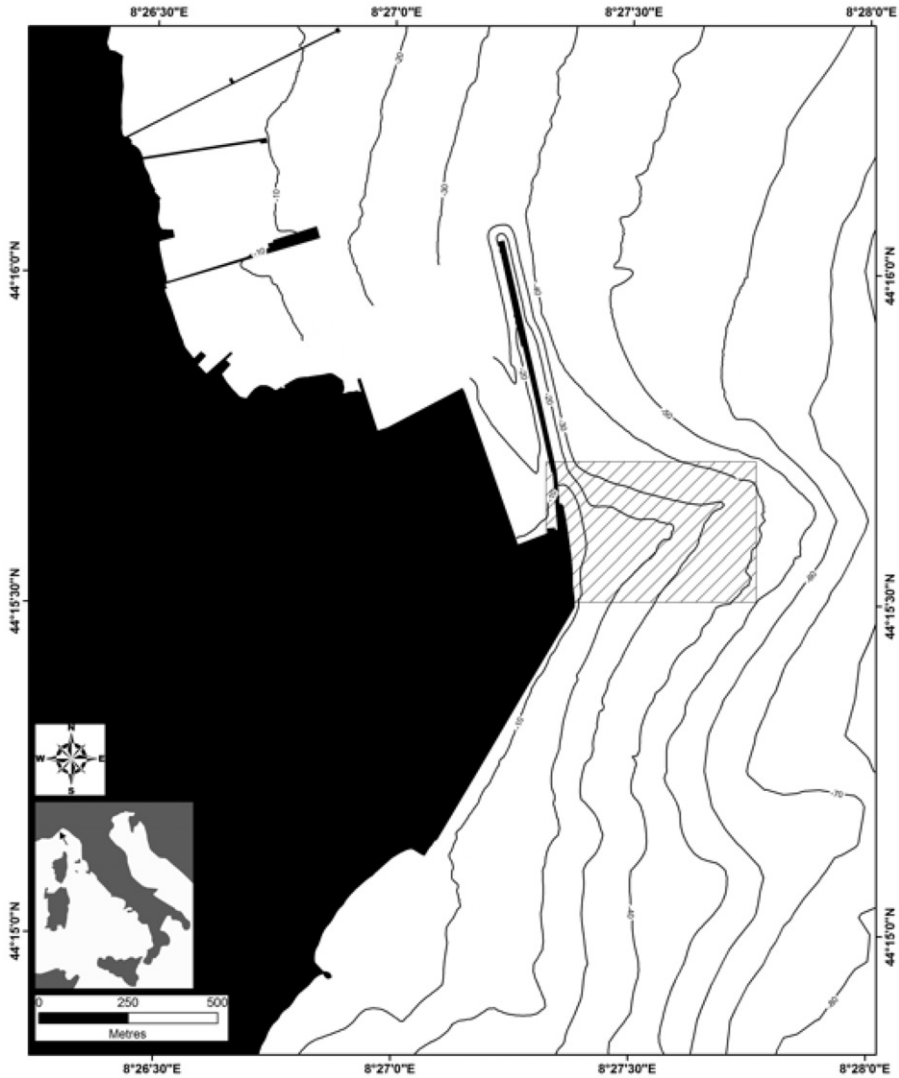


Figure 1. Vado Ligure harbour and location of the study area (dashed surface).

## 2.2. Data management

### 2.2.1. Characterisation

From the quali-quantitative composition of the upper layer, the dominant species allowed for the definition of the habitat types that characterised the coralligenous shoals of Vado Ligure, according to the European Nature Information System (EuNIS) [33], which is based on the classification systems of Pérès and Picard [34] and UNEP-RAC/SPA [35]. Geomorphologic and abiotic features associated to each habitat type identified were summarized in a table in order to obtain a comprehensive characterisation of the shoals.

### 2.2.2. Quality assessment

The quality of the coralligenous in each survey was assessed for each layer individually using different quality descriptors. Thickness of the concretion and occurrence of marks of borers provide a measure of the state of the bioconstruction. Biodiversity of the intermediate layer and occurrence of sensitive taxa, such as erect bryozoans, are known to be severely influenced by changing environmental conditions [18,35]. Occurrence of long-living species in the upper layer, such as massive sponges and gorgonians, informs on the three-dimensional structure and aesthetic value of the seascape.

A total of nine descriptors, three for each layer, were used and results were converted into quality scores ranging from 1 (bad quality) to 3 (good quality). The following criteria were adopted to assign quality scores to each descriptor.

#### Upper layer:

- *total cover of species*: score 1 was assigned when cover < 5%, score 2 when  $5\% \leq \text{cover} \leq 25\%$ , score 3 when cover > 25%, according to Pérès and Picard [34];
- *maximum height (MH)*: the maximum height of the tallest species was compared to the maximum height value available in literature (LMH) for that species. Score 1 was assigned when  $MH < 0.5 \text{ LMH}$ , score 2 when  $0.5 \text{ LMH} \leq MH \leq 0.75 \text{ LMH}$ , score 3 when  $MH > 0.75 \text{ LMH}$ ;
- *epibiosis-necrosis (EN)*: from the percentage of epibiosis and/or necrosis of organisms, score 1 was assigned when  $EN > 75\%$ , score 2 when  $10\% \leq EN \leq 75\%$ , score 3 when  $EN < 10\%$ .

#### Intermediate layer:

- *specific richness (SR)*: preliminary investigations showed that, over an area of approximately  $2 \text{ m}^2$ , the maximum number of conspicuous species detected in two minutes was about 15. Then, score 1 was assigned when  $SR < 5$ , score 2 when  $5 \leq SR \leq 10$ , score 3 when  $SR > 10$ ;
- *seasonal-perennial species ratio (S/P)*: the persistence of coralligenous assemblages is strictly dependent on the maintenance of definite abiotic and biotic factors [35]. The dominance of seasonal life cycles may indicate opportunistic strategies, which typically occur under high disturbance regimes and unstable conditions; on the contrary, the dominance of long lived species may indicate environmental stability or good adaptation to predictably variable conditions. Therefore, the ratio between the number of seasonal and perennial species was calculated and score 1 was assigned when  $S/P > 0.5$ , score 2 when  $0.5 \leq S/P \leq 0.2$ , score 3 when  $S/P < 0.2$ ;
- *erect calcified bryozoans (ECB)*: according to Hong [18,35], ECB have an important ecological role, since they are the most abundant bioconstructors among animals and their presence is an indicator of low human impact. Considering the number of species of erect bryozoans, score 1 was assigned when  $ECB = 1$  species, score 2 when  $ECB = 2$  to 4 species, score 3 when  $ECB > 4$  species.

#### Basal layer:

- *NTDs cover*: depending on their role in the bioconstruction, score 3 was assigned to ECR, because they are the main active producers of calcareous substrate; score 2.5 to NCEA and AN for their role in substrate protection; score 2 to TURF,

which may protect the substrate but retains sediment; score 1 to SED, because its presence inhibits bioconstructors' growth and may contribute to the abrasion of calcareous substrate. The formula  $(cover \times score)/100$  was applied to percent cover of each NTD and resulting values were summed up to obtain the total quality score relative to NTDs cover in the basal layer of each survey;

- *thickness and consistency of calcareous layer*: score 1 was assigned when penetration was null, meaning that the calcareous substrate was either absent or completely lithified (i.e. bioconstruction was not more active); score 2 was assigned when penetration was centimetric, suggesting the presence of an unconsolidated calcareous substrate that results from an active bioconstruction with little or no consolidation, undermined by the action of biotic and abiotic erosion; score 3 was assigned when penetration was millimetric, suggesting the presence of active bioconstruction resulting in a compact calcareous biogenic substrate;
- *borer marks*: score 1 was assigned when borers were common, score 2 when they were occasional and score 3 when they were absent.

In order to get a total quality score for each layer ( $Q_L$ ) in each survey, the following formula inspired by the one adopted by Bianchi [37], was applied:

$$Q_L = (X_L \times Y_L \times Z_L) \times k^{(1-n)}$$

where  $X_L$ ,  $Y_L$  and  $Z_L$  are the quality scores assigned to the three descriptors,  $k$  is the maximum value assumed by these scores (3 in this case),  $n$  is the number of descriptors considered. In our experience, adoption of an additive model like arithmetic mean is inappropriate, because very different configurations of sub-scores (quality scores of descriptors, in our case) would give the same integrated value ( $Q_L$ ). Therefore, we used this multiplicative formula that guarantees to obtain a  $Q_L$  score that reflects the configuration of each sub-score [38].

According to the ecological status classification of the Water Framework Directive and its chromatic scheme,  $Q_L$  was divided into five classes of quality status: Bad (red) when  $0 < Q_L \leq 0.6$ ; Poor (orange) when  $0.6 < Q_L \leq 1.2$ ; Moderate (yellow) when  $1.2 < Q_L \leq 1.8$ ; Good (green) when  $1.8 < Q_L \leq 2.4$ ; High (blue) when  $2.4 < Q_L \leq 3$ .

Finally, among  $Q_L$  values of each layer belonging to each habitat type, the maximum  $Q_L$  value (max  $Q_L$ ) was assumed as the synthetic quality index of the habitat type.

### 3. Results

#### 3.1. Characterisation

The multi-beam survey showed a system of rocky shoals at Vado Ligure, scattered between 14 m and 40 m depth. Shoals 1, 2, and 4 were located between 20 m and 30 m depth, shoal 3 had rocky outcrops developing down to 30 m depth, whilst shoal 5 was shallower than 20 m (Figure 5).

Three habitat types were defined on the basis of the main species that dominated the upper layer (Figure 2), all belonging to the same EuNIS habitat "Mediterranean coralligenous communities moderately exposed to hydrodynamic action" (code A4.26). The "A" habitat type (EuNIS code A4.26B, "Facies with *Paramuricea clavata*") is dominated by the sea fan *Paramuricea clavata*, which was occasionally associated to other

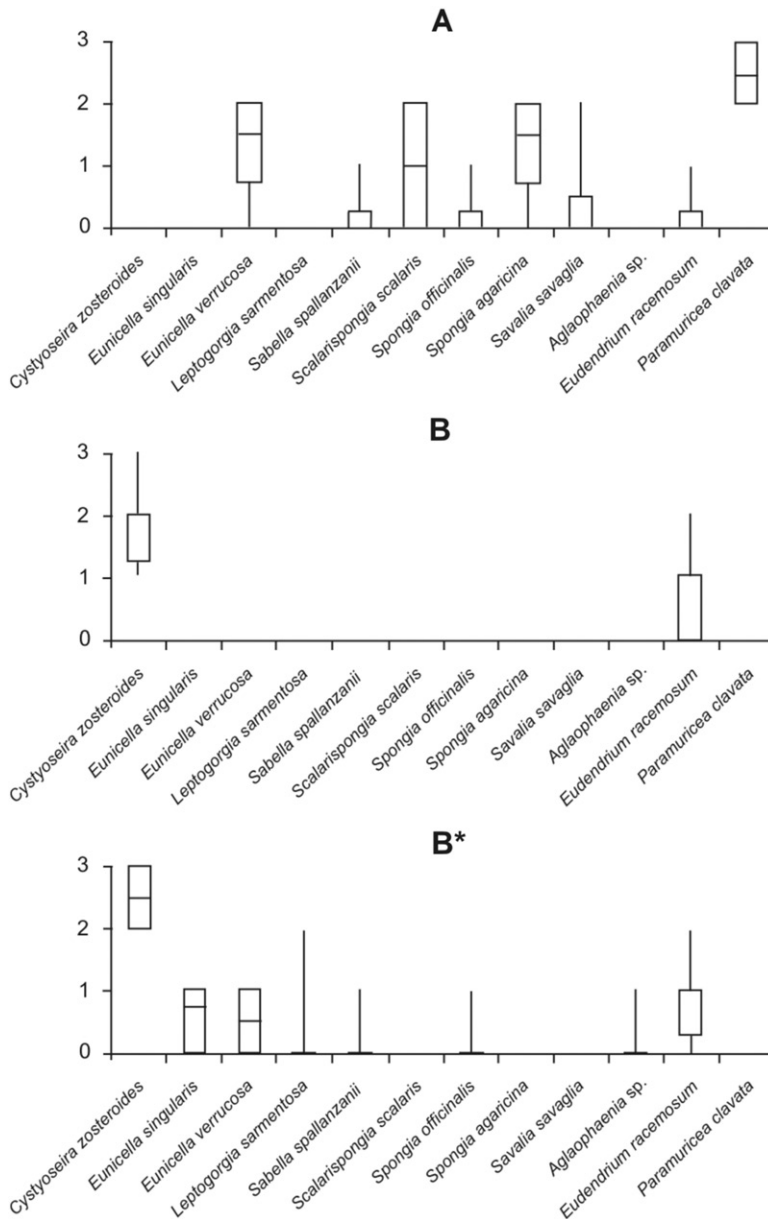


Figure 2. Box and whiskers plot representing species composition and classes of abundance of the upper layers in the three habitat types: A = Facies with *Paramuricea clavata* (EuNIS code A4.26B); B = Association with *Cystoseira zosteroides* (EuNIS code A4.261); B\* = ditto together with gorgonians.

gorgonians (*Eunicella verrucosa*, *Eunicella singularis*), the antipatarians *Savalia savaglia*, sponges (*Scalarispongia scalaris*, *Spongia officinalis*, *S. agaricina*) and the polychaete *Sabella spallanzanii*. This habitat type was found only in the shoal 3. The “B” habitat type (EuNIS code A4.261, “Association with *Cystoseira zosteroides*”) was characterised by the

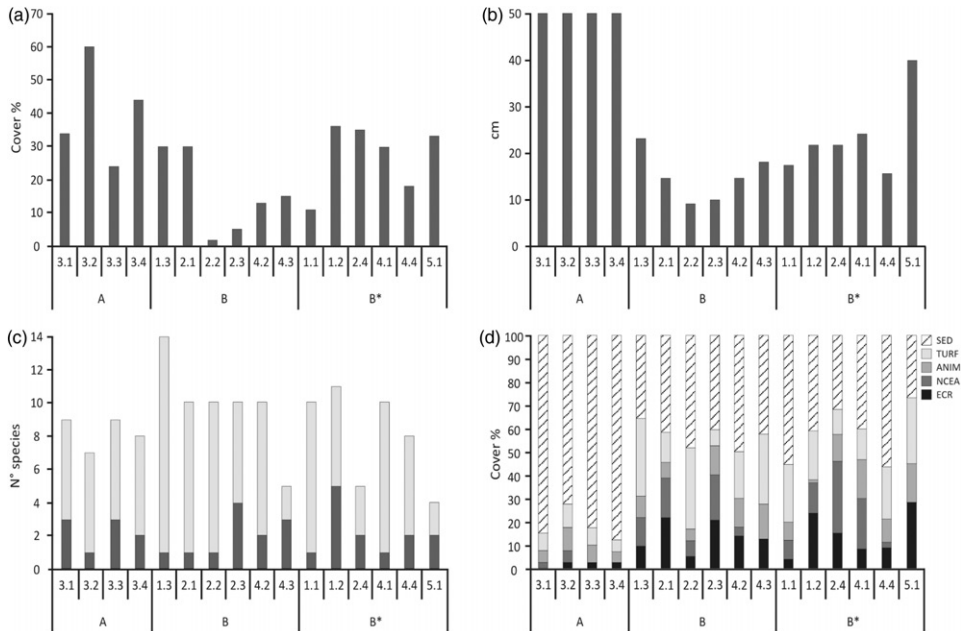


Figure 3. Percentages of cover of the upper layer's species (a); maximum height of the upper layer's species (b); number of species detected in the intermediate layer, with the dark portion representing erect bryozoans (c); percentages of cover of the five NTDs in the basal layer (d). SED = sediment, TURF = turf-forming algae, ANIM = encrusting animals, NCEA = non-calcified encrusting algae, ECR = encrusting calcified rodhophyta.

brown seaweed *Cystoseira zosteroides* together with tall colonies of *Eudendrium racemosum*. This type was widely distributed in the shoals of Vado Ligure (Figure 3). The “B\*” habitat type corresponds to the previous EuNIS habitat “Association with *Cystoseira zosteroides*” (code A4.261) but gorgonians (*E. verrucosa*, *E. singularis*, *Leptogorgia sarmentosa*) occurred together with *Cystoseira zosteroides* and *Eudendrium racemosum*. Also this habitat showed a wide distribution at Vado Ligure (Figure 3). Geomorphologic and mesologic characteristics associated to each habitat type are summarised in Table 1.

### 3.2. Quality assessment

Species of the upper layer had total cover values ranging from 2% to 60% (Figure 3a). Maximum height (MH) of the tallest species varied from 50 cm of some *Paramuricea clavata* colonies to 9 cm of *Cystoseira zosteroides* (Figure 3b). Comparing MH values with the maximum height values found in literature (LMH), quality scores have been defined as shown in Table 2. Epibiosis and necrosis usually exceeded 75%, with the exception of surveys 1.1, 1.2, 4.1 where comparatively lower values ( $EN < 10\%$ ) were detected.

Specific richness (SR) of the intermediate layer varied between 4–14 species (Figure 3c and Table 3). The number of erect bryozoans ranged between 1–5. Seasonal and perennial species ratio (S/P) was always lower than 0.25 and, in the 50% of surveys, conspicuous seasonal species were absent.



Table 1. Geomorphologic and mesologic characteristics associated with each habitat type, with their respective EuNIS code.

Habitat type	Morphotype	Depth (m)	Slope (°)	Elevation (m)	EUNIS code
A	HR, LR	31–34	15–30	1 m–3 m	A4.26B
B	HR	20–23	5–80	2.5 m–5 m	A4.261
B*	HR, LD, LR	17–27	5–45	1 m–6 m	A4.261

Table 2. Quality scores associated with the classes of height of the upper layer species.

Score	<i>Cystoseira zosteroides</i>	<i>Paramuricea clavata</i>	<i>Eunicella singularis</i>	<i>Eunicella verrucosa</i>	<i>Leptogorgia sarmentosa</i>
1	< 15 cm	< 40 cm	< 20 cm	< 20 cm	< 30 cm
2	15–20 cm	40–60 cm	20–30 cm	20–30 cm	30–50 cm
3	> 20 cm	> 60 cm	> 30 cm	> 30 cm	> 50 cm

In the basal layer, sediment always showed the highest cover values, in some cases exceeding 80% (Figure 3d). As a consequence, quality scores obtained from the cover descriptor were always lower than 2 (see Table 4). Penetration of calcareous substrate was null in the 50% of the surveys; only in a single case (survey 2.4) it was higher than 2 cm. Borer marks were always absent, except for the occasional occurrence of *Cliona viridis* papillae in survey 1.3.

Quality scores for each layer, derived from the nine descriptors, are summarized in Table 4. The total quality scores per layer ( $Q_L$ ) never exceeded score 2 and were often lower than 1 (52%) (Figure 4). Following the ecological status classification of the WFD (Figure 5), the basal layer showed Bad status in seven surveys (more than half being found in the shoal 4), Poor in five (mostly found in shoal 3), Moderate in three and Good in only one survey (in shoal 2); the intermediate layer had Bad status in one survey (shoal 2), Poor in five, Moderate in seven and Good in three surveys; the upper layer showed seven surveys with Bad status (mostly found in shoals 2 and 4), two with Poor and Good, five with Moderate status (more than half in shoal 3).

The ecological status of each layer in the three habitat types, considering the synthetic quality index (max  $Q_L$ ), resulted as follow (see Figure 4):

- type A: basal and upper layers in Moderate status (max  $Q_L = 1.4$  and 1.3, respectively), intermediate layer in Good status (max  $Q_L = 2$ );
- type B: basal and intermediate layers in Good status (max  $Q_L = 2$ ), upper layer in Moderate status (max  $Q_L = 1.3$ );
- type B\*: basal layer in Moderate status (max  $Q_L = 1.6$ ), intermediate and upper layers in Good status (max  $Q_L = 2$ ).

#### 4. Discussion

To date, no general consensus has been achieved in the definition of coralligenous, being defined as eco-ethological crossroad [17], biocoenosis [18], polybiocoenotic entity [39],

Table 3. List of species of the intermediate layer.

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Algae
<i>Codium bursa</i>
<i>Dictyopterus polypodioides</i>
<i>Dictyota dichotoma</i>
<i>Flabellia petiolata</i>
<i>Halimeda tuna</i>
Porifera
<i>Acanthella acuta</i>
<i>Agelas oroides</i>
<i>Axinella damicornis</i>
<i>Axinella verrucosa</i>
<i>Chondrosia reniformis</i>
<i>Clathrina clathrus</i>
<i>Dysidea avara</i>
<i>Dysidea</i> sp.
<i>Haliclona cratera</i>
<i>Hemimycale columella</i>
<i>Ircinia variabilis</i>
<i>Oscarella lobularis</i>
<i>Petrosia ficiformis</i>
<i>Pleraplysilla spinifera</i>
Hydroida
<i>Aglaophenia</i> sp.
<i>Garveia grisea</i>
Anthozoa
<i>Aiptasia mutabilis</i>
<i>Balanophyllia europaea</i>
<i>Cerianthus membranaceus</i>
<i>Cladocora caespitosa</i>
<i>Condylactis aurantiaca</i>
<i>Parazoanthus axinellae</i>
<i>Phyllangia americana mouchezii</i>
Serpuloidea
<i>Protula tubularia</i>
<i>Salmacina dysteri</i>
Bryozoa
<i>Bugula fulva</i>
<i>Bugula plumosa</i>
<i>Myriapora truncata</i>
<i>Pentapora fascialis</i>
<i>Reteporella grimaldii</i>
<i>Rhynchozoon</i> sp.
<i>Schizoporella errata</i>
<i>Smittina cervicornis</i>
Tunicata
<i>Clavelina lepadiformis</i>
<i>Halocynthia papillosa</i>

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assemblage [40], community [41], community puzzle [19] and seascape [42,13]. We embraced the latter definition of coralligenous as a seascape, because its heterogeneity reflects exactly the mosaic of habitat patches forming a landscape [43]. A seascape approach describes relationships between ecological processes and environmental patchiness and between spatial configuration of habitats and typology of territorial elements [44]. The choice to combine geomorphology, mesology and bionomy, as proposed earlier

Table 4. Quality scores assigned to descriptors in the three layers for each survey.

Descriptors		1.1	1.2	1.3	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4	5.1
Upper	Cover	2	2	2	2	1	1	2	3	3	2	3	2	2	1	2	2
	Maximum height	2	3	3	2	1	1	3	2	2	2	2	3	2	2	2	2
	Epibiosis – Necrosis	3	3	2	1	1	1	1	2	2	2	2	3	1	1	1	1
Intermediate	Species richness	2	3	3	2	2	2	1	2	2	2	2	2	2	1	2	1
	Seasonal/Perennial	3	2	3	3	2	3	3	3	3	3	3	3	3	3	3	3
	Bryozoans	2	1	2	2	1	1	2	3	2	2	2	3	2	2	2	3
Basal	Cover	1.6	1.9	1.8	1.9	1.6	2.0	2.0	1.2	1.4	1.2	1.2	1.9	1.7	1.8	1.6	2.1
	Penetrometry	3	1	3	1	1	3	2	3	3	2	2	1	1	1	1	1
	Borers	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3

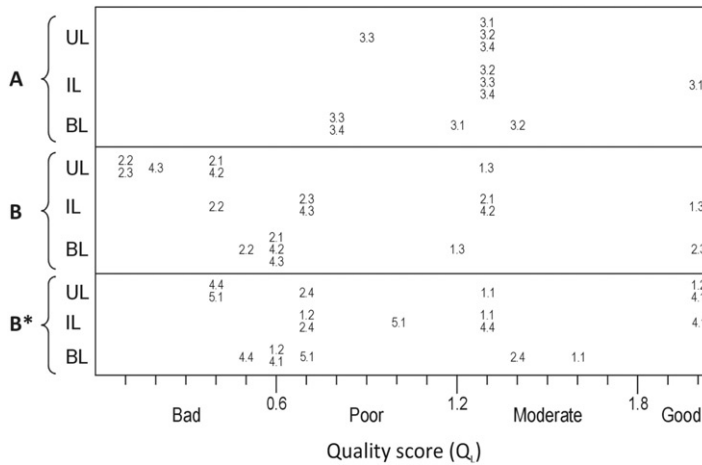


Figure 4. Quality scores per layer ( $Q_L$ ) of each survey grouped in the three habitat types. A = Facies with *Paramuricea clavata*; B = Association with *Cystoseira zosteroides*; B\* = Association with *Cystoseira zosteroides* and gorgonians. UL = upper layer; IL = intermediate layer; BL = basal layer. Classes of the ecological status classification of the Water Framework Directive are also reported (from Bad to Good status).

by Cocito et al. [26], resulted in an effective way to characterise and evaluate the quality of coralligenous assemblages. This approach is consistent with the indication of the Marine Strategy Framework Directive (MSFD) to integrate abiotic and biotic features for assessing the ecological status of marine habitats. Although preliminary, this first description of the coralligenous shoals of Vado Ligure was obtained using some of the indicators proposed by the MSFD for seafloor integrity assessment [45], such as the status of the biogenic substrate (thickness and consistency of calcareous concretion in our case), the presence of sensitive species, the benthic community condition and functionality (e.g. species richness), the number of individuals over a specified size. The employment of a Rapid Visual Assessment technique (RVA) solved most of the constraints linked with the

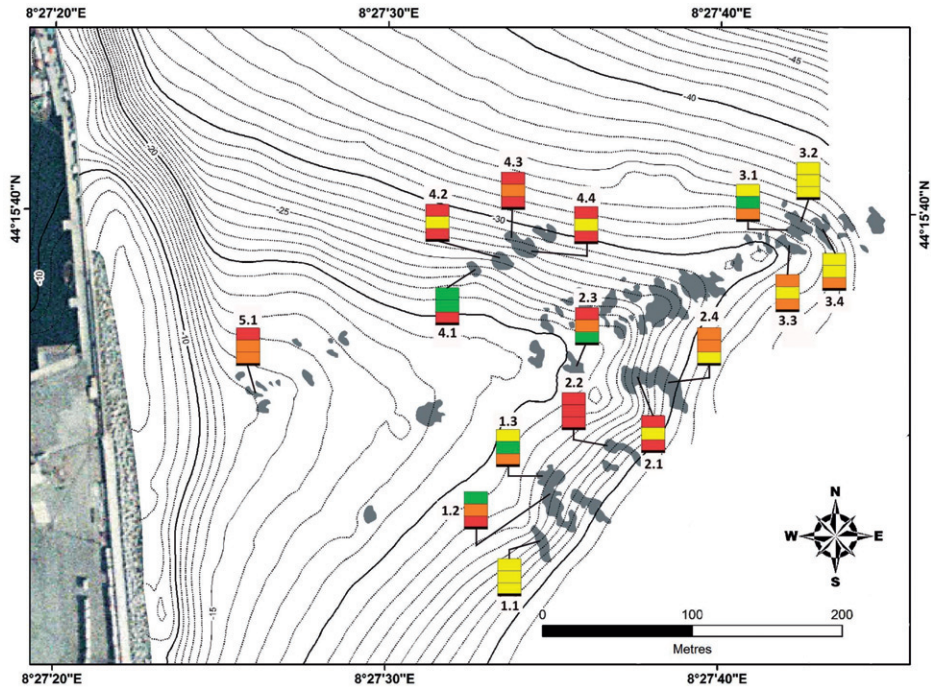


Figure 5. Quality scores per layer in each survey represented according to the chromatic scheme of the WFD. Red = Bad status; orange = Poor status; yellow = Moderate status; green = Good status; blue = High status.

wide bathymetric distribution of coralligenous: it optimised underwater work allowing the direct collection of a sufficient amount of data with a congruent diving effort. The RVA turned out to be much effective when joined with a detailed cartography of the seafloor: the preliminary map based on the multi-beam surveys was indispensable to localise exactly each rocky outcrop and to better finalize field activities.

A first characterisation of the coralligenous shoals of Vado Ligure was achieved through the recognition of habitat types as defined by the EuNIS classification on the basis of the dominant species of the upper layer [46, 33]. High rocky outcrops below 30 m depth showed the A habitat type, i.e. the facies with *Paramuricea clavata*. This habitat was always associated with the highest values of sediment cover in the basal layer. Landslide deposits and rocky outcrops between 17 m and 30 m depth had the B habitat type, i.e. the association with *Cystoseira zosteroides*. At Vado Ligure, *Cystoseira zosteroides* was often found together with gorgonians, thus calling for the necessity to define this variant of the habitat B as a new habitat typology, namely B\*. In both B and B\* habitats the basal layer was characterised by a higher percentage of encrusting calcified rhodophyta (ECR) than the habitat A: G. Giaccone observed a positive relationship between active bioconstruction in the basal layer and the occurrence of *Cystoseira zosteroides*, instead of dense gorgonian canopies, in the upper layer (personal communication).

Although sediment cover may be strongly affected by short-term hydrodynamic condition, the high cover of sediment in the basal layer and the concomitant occurrence of species indicative of turbidity, such as *Eunicella verrucosa* and *Leptogorgia sarmentosa* [47],

Table 5. Concordances and discordances of the total quality score ( $Q_L$ ) between layers.

	CONCORDANCE	DISCORDANCE
All Layers	4	12
Upper × Intermediate	7	9
Upper × Basal	8	8
Intermediate × Basal	6	10

suggest that high sedimentation rate is possibly the main stressor affecting the coralligenous of Vado Ligure. Our results are consistent with the situation observed in other areas of the Ligurian Sea, e.g. the “Cinque Terre” marine protected area (La Spezia, Italy), where high turbidity and sedimentation rate were associated with the same species of gorgonians [48 and references therein]. High sedimentation was also locally associated with low cover by encrusting algae in the basal layer and with the absence of *Cystoseira zosteroides* from the upper layer [49 and references therein, 50]. This confirms a negative influence of sedimentation on the structure of coralligenous assemblages [51]. Although both the basal and the upper layers exhibited a clear response to water turbidity and sediment deposition, no evidences of such impacts had been shown by the intermediate layer. The different dynamics observed in the three layers of the coralligenous [27,52] justify our choice to keep them separated, both operationally during field activities and analytically during assessment of their quality.  $Q_L$  scores of the three layers were different in most of the cases and the resulting quality states were often discordant among layers (Table 5). A “global” quality index computed from the  $Q_L$  values of the three layers taken together would be, therefore, inappropriate to depict the overall status of the coralligenous seascape. Working on distinct layers would also be useful in response to specific objectives of management and conservation: when the major interest is the aesthetic value, for instance, efforts should be focused on evaluating the nature and the three-dimensional structure of the upper layer; when the focus is biodiversity, the intermediate layer would be an opportune proxy; finally, if the goal is the maintenance of bioconstruction, the quality of the basal layer would be the most informative. As we did in our study, the synthetic quality index (max  $Q_L$ ) grouped together the values of surveys belonging to each habitat type per layer. Alternatively, a synthetic quality index could be computed either for each shoal (grouping  $Q_L$  values of each survey on this shoal) or for the whole system of shoals in the area. Three different methods can be adopted for computing a synthetic quality index starting from a number of quality indices, i.e. summing values, averaging values and considering the maximum value, each with its pros and cons (Table 6). The max  $Q_L$  index we used in this study was computed from the maximum value of  $Q_L$  indices belonging to each habitat type: with this method, the potentiality of coralligenous assemblages is evidenced, thus providing indications for undertaking protection measures, as required by the MSFD [53]. Although the quality of the coralligenous of Vado Ligure was found Bad or Poor in most cases, the max  $Q_L$  ranged from Moderate to Good, thus suggesting that these assemblages may have the potential to recover if chronic stresses such as sedimentation is properly addressed by conservation measures. When the main aim is to assess the overall quality of habitat types, the use of the mean  $Q_L$  would be more

Table 6. The three main methods that can be used to obtain the synthetic quality index of the habitat type from  $Q_L$  scores of each layer belonging to each habitat type, with their respective pros and cons.

Method	Pros	Cons
Sum of the values of surveys (sum $Q_L$ )	It takes into account the surplus value of ecodiversity	The number of surveys must be balanced
Maximum value of surveys (max $Q_L$ )	Surveys with high values and potentiality of layers are evidenced	It does not consider ecodiversity
Mean of the values of surveys (mean $Q_L$ )	Many surveys with low value give a low value of the synthetic quality index	Averaging low values with high values produces mediocrity

appropriate. Selection of the method for computing the synthetic quality index should be guided by the objective of the study.

The approach we proposed has been developed and applied for the first time to characterise the status of the coralligenous shoals in the specific area of Vado Ligure. The RVA technique combined with the seascape approach results were promising, although some improvements are necessary and applications in other areas are needed in order to make it repeatable, comparable and to reduce the subjectivity of underwater operators.

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