Characterization of North–Western Mediterranean coralligenous assemblages by video surveys and evaluation of their structural complexity

(Article begins on next page)

25 November 2024

Characterization of North Western Mediterranean Coralligenous assemblages by video surveys and evaluation of their Structural Complexity

Laura Valisano[a], Marco Palma[a], Ubaldo Pantaleo[a], Barbara Calcinai[a], Carlo Cerrano[a,*]

[a]*DISVA via Brecce Bianche, Monte Dago, 60132 Ancona (Italia)*

Abstract

The increase of awareness regarding the key ecological role of coralligenous habitats in the Mediterranean Sea is addressing several research projects to standardize protocols for the description of its main features and conditions. Here we examined 13 stations along the Italian coast of the Western Mediterranean Sea, using video-transects technique, comparing the structure of coralligenous assemblages and testing the importance of their tridimensional complexity as a proxy to define their level of integrity. We considered the nature of substrata, the entity of injury and marks of anthropic impacts. The analysis of the stations allowed to develop a gradient in the coralligenous conditions, evidencing the most rich in species and diverse stationss and the site with the highest equitability. Here we develop a method to evaluate coralligenous complexity, selecting Structural Descriptors to define the systems tridimensional structure and to assess a unique Index of 3D - Structural Complexity for the system coralligenous, that identified the stations with the highest and the lowest tridimensional complexity.

Keywords: Bioconstructions, Thyrrenian Sea, 3D, health index, animal forest.

*Corresponding author
    Email address:* `c.cerrano@univpm.it` (Carlo Cerrano)

1. Introduction

The coralligenous is a typical coastal Mediterranean biogenic formation inhabited by a peculiar biota [75]. It is dominated by calcareous organisms, consisting of blocks of organic concretionary material, originated primarily by accumulation of dead thalli of coralline algae and secondarily by calcareous skeletons of animals as polychaetes and bryozoans [4]. The bioconstructions that constitute the coralligenous are formed by species that, with the superposition of skeletons of previous generations, change the primary geological habitats creating a secondary hard substrate, representing a privileged habitat for the settlement, spawning, recruitment, feeding and shelter of an enormous variety of marine species. It is a key ecosystem recognised as a natural habitat of community interest and Zone of Special Conservation at European level (92/43/CE Habitat Directive [34], habitat code 1170-14: Reefs, coralligenous assemblage). In the Mediterranean Sea, coralligenous assemblages [65, 76] develop in dim-light littoral systems (between $25 - 30$ and $150 - 200$ m depth) on vertical rocky cliffs and on flat or semi-flat biodetritic bottoms [90, 92], wherever irradiance is reduced between $2 - 3\%$ and $0 - 0.5\%$ of the surface irradiance [37] and in relatively constant conditions of temperature, currents and salinity. The unique information available regarding growth dynamics evidences a very low growth rate, 0.19 mm $year^{-1}$, ranging from 0.11 to 0.26 mm $year^{-1}$ [77]. Simplifying the scheme of [71] it is possible to recognize four levels of organization, due to cryptic/boring, encrusting, massive, and arborescent organisms. Perforating and insinuating forms may affect the interface water/substrate [12, 16], encrusting and massive specimens help to trap and stabilize sediment [25] erect organisms reduce light penetration and water movement [79]. The integrity of these layers is able to affect not only the chemico-physical equilibrium of coralligenous rims but also their biological dynamics and associated fauna [70, 69]. The typical abrasive effects that human activities play on sea floor, on mature coralligenous communities act primarily on the most exposed layers. Once these layers are damaged, lower layers start to be involved in further erosion, down

2

to the coralligenous bioconcretion. This process leads to the fragmentation of the populations involved in the structuring of coralligenous assemblages. These effects can be faced only with a quick interruption of the activities playing the impact. If this does not happen, the community begins to offer space to new pioneer and/or opportunistic species triggering new successional stages. Owing to its fragility, coralligenous assemblages are particularly sensitive to mass mortality events, mainly due to increase of temperature of water column and climate changes [23, 49] and to a series of stressors of anthropic origin affecting the coralligenous architecture and functioning [85]. Anchorage and fishing activity, especially recreational and artisanal, negatively affect the structure of coralligenous communities [50]. The large-size epifaunal invertebrates, such as arborescent sponges and gorgonians, can clearly be affected by mechanical stressors and show the injuries also for years after the event of damage [7]. Moreover, the documented general increase of turbidity and sedimentation along coastal areas [56], can compromise mainly suspension feeders [14, 64]. Pollution and wastewaters affect richness and density of the biggest epifaunal species and increase the abundance of most tolerant ones and bioeroders [47]. In case of turbidity and pollution bioeroders are represented mainly by Porifera, and can play a key role in the accretion dynamics [24]. In areas particularly known for their naturalistic value, diving tourism [74] impacts mainly on the large-size invertebrates of the coralligenous communities [28] and affect organisms with slow-growing and fragile skeletons [40, 54]. Finally the coralligenous communities are threatened by the invasion of non indigenous species, such as ones of the genus Caulerpa, the most common green alga invading all kind of substrata from 0 to 40 m depth [84] and affecting key ecosystem functions and services, or Womersleyella setacea, a red turf alga forming dense carpet, enhancing sediment trapping [1] and inhibiting photosynthesis and growth of coralligenous builders [67, 5]. It is essential to develop a correct interpretation of coralligenous health status, according to the Marine Strategy Framework Directive adopted in 2008, whose purpose is to join a Good Environmental Status (GES) of European marine waters within 2020. Destructive methods have been used for long time because

3

of excellent results for studying sessile organisms, particularly suitable for studies with strong taxonomical components, but they are not suitable for studies on assemblages and long-time monitoring, leading to the necessity to use other non-destructive methods of investigation, such as transects or quadrats. The study of bioconstructions, such as coralligenous accretions in the Mediterranean Sea, provided up today important general knowledge concerning the composition of benthic communities [4, 42, 21]. The lack of detailed cartographic data of the distribution of this habitat at small scale represents the most important gap for the development of well focused management plans [91]. Recent papers modelled the distribution of coralligenous habitats at basin scale [43, 55] and at local scale [92]. In the NW Mediterranean region [21] evidenced, after a study lasted five years, moderate/low spatial and temporal variability in assemblages composition. Anyway, a standard and common protocol is still lacking, delaying a shared conservation strategy for the Mediterranean Sea. Up today, efforts in listing of species [10, 84], genetics [30, 61] and cartography [91, 92] are among the main used approaches, as the focus on environmental factors and impacts of climate changes. In this work, we examined 13 stations along Italian coasts. The recording of video-transect allowed us to apply non-invasive methods to collect covering data. A list of 28 phytobenthic and 97 zoobenthic taxa were considered. In addition, regarding gorgonians, we estimated the entity of injury, the covering of epibionts, marks of anthropic pressure, and the nature of substrata. The analysis of covering data allowed us to evidence and compare richness and diversity for each site. Moreover we proposed a method to define different typologies of coralligenous, based on different structural descriptors (SD), describing the 3D architecture of the system. The approach allows to define different levels of architectural complexity for the coralligenous and to assess an Index of 3D - Structural Complexity, avoiding complex time-consuming methodologies as chain transects or 3D reconstructions.

4

2. Material and methods

2.1. Studied sites

The study focused on 6 sites, 13 stations (Table 1) along the NW Italian coasts (Figure 1).

- Santo Stefano shoal, in the Ligurian Sea, develops perpendicularly to the coast, for about 3 km. It has a profile of about 8 km and it is about 300 m large close to the coast side, with a wide tip at seaward side. At 25 meters of depth, on the top of the shoal, a *Posidonia oceanica* meadow is mixed with detritic sediments and coralligenous pinnacles. The eastern side, exposed to the main littoral Ligurian current flowing westwards [86], is characterized by a coralligenous habitat developing on a vertical cliff, mainly structured by a *Paramuricea clavata* facies. At 30−40 m depth, the base of the cliff is characterized by a discontinuous belt of boulders wrapped by coralligenous rims [84]. The western side is undercurrent, very silty, with a wall leaning slightly. Here we considered four stations, La Luna (SSLu), Canyon (SSCa), Croce Cappello (SSCC) and S Croce (SSCr).

- Gallinara Island, in the Ligurian Sea, is 1.5 km far from the main coast and the separation channel is 12 m deep. The coastal line is constituted by a rocky cliff and the bottom is rocky reaching a depth of 30 40 m, where organogenous debris and mud mainly characterize the sediment. The numerous biocoenosis biocoenoses reflect the heterogeneity of the substrata, varying from biocoenosis typical of hard substrata at lower depths to Posidonia meadows and detritic-muddy bottom at higher depths. Here we considered two sampling stations, Punta Sciuscia in the southeastern side and Punta Falconara in the southwestern side..

- MPA of Portofino: Portofino Promontory has a coastline of 13 km and its geomorphologic characteristics determine an environment rich of gorges and small caves that favour the development of a rich benthic fauna. *P.*

5

oceanica meadows develop inside the bays and in tracts with lower slope, while the coralligenous, characterized by the presence of *P. clavata, Eunicella species, C. rubrum* and rich populations of sponges, cnidarians and ascidians, dominate the rocky cliff extending beyond 50 m depth, followed by detritic bottom. Here we considered three stations PTF sect 1, PTF sect 2 and PTF sect 3.

- Punta Manara: .It is a wide promontory 15 km Eastern from close to Portofino MPA. Here the rocky bottom is mainly built by big rocks coming from the upper cliff likely related to ancient landslides and bioconstructions. The coralligenous starts on the rocky shoals located at 24 m depth and develops down to -85 m depth. Here we monitored one station (PM).

- MPA of Tavolara and Punta Coda Cavallo: Tavolara is an island of a small archipelago characterized by limestone-dolomite rock [6], whose epibenhic community has been described by [63] and [62]. Here we considered two nearby stations, Papa 1 (TVP1) and Papa 2 (TVP2), the first ranging from 15 to 39 m, the latter from 24 to 43 m. Both the stations are populated by forests of *P. clavat* and *E. cavolinii* [17, 13].

- MPA of Secche di Tor Paterno: this the only offshore MPA in Italy and the shoal is a compact aggregation of rocky outcrops, developing for 4 km from 18 m to roughly 50 m depth. The system is characterized by *P. oceanica* meadows and coralligenous biocoenoses, and is affected interested by the Tevere River outfall. The area is populated by *P. clavata* and Eunicella species. Here we monitored one station (TP).

2.2. Data collection

Data were collected in the 13 stations by 10 meters long video-transects recorded from 2004 to 2008 (months from May to June) between 27 and 35 meters depth, by using a camera Sony HVR-A1 with modality HD (1080i),

6

equipped with underwater Amphico housing and Hartemberger lighting system. A specific depth range was selected in order to avoid the potential effect of depth in the outcome of the surveys. Surveys were conducted at constant depth and speed of 5 meter for minute, for both run directions, both above and below the tape positioned to track the transect, in order to amplify the sampled surface and reduce the redundancy of data. Videos recorded on magnetic support (miniDV) were acquired by software FinalCut PRO and a greed 10 x 10 was superimposed in timeline through trasparencetransparency immage (lumakey effect) for 1 second of duration each 4 second in the central portion of the frame of videos, in order to elude effects of distortion of image due to the lenses of the camera. Covering data were collected by analyzing freeze-frames of the videos with superimposition of the grid 10 x 10, choosing 0.25 % as level of precision of covering of the whole area of each square of the grid. Organisms were visually identified at the lowest possible taxonomic level and assigned to systematic and/or ecological groups, formulating a list of categories that was checked during reading of the video-transects in order to assess their presence and abundance. Moreover we estimated the entity of injury or necrosis, the nature of substrata, epibiosis and marks of anthropic damage as the presence fishing-lines.

2.3. Data analysis

Covering data of species belonging to coralligenous assemblages of the 13 stations were square root transformed and Bray-Curtis similarities were calculated. Data were analysed with permutational multivariate analysis of variance PERMANOVA (Permutational ANOVA and MANOVA) [2, 57] under the unrestricted permutation of raw data (9999 permutations) and Principal coordinates analysis (PCO) [83, 44] with Spearman correlation > 0.5. The Analysis of Similarities Percentages (SIMPER) were used to evidence contributions to the variability of the stations in order to identify species or families characterizing the studied stations The Diversity Analysis was performed for the stations in exam by calculating Margalef Richness, Shannon Diversity and Pielous even-

ness indexes for each assemblage (shown in graphics as means ± SE). Data were square root transformed, normalized and analysed using PERMANOVA, Pair-wise tests on Euclidean distances, with unrestricted permutation of raw data (9999 permutations) and Principal Component Analysis (PCA). Observed diversity was compared with theoretical expected diversity of Caswell's neutral model [22] and the V statistics was used to test the deviation from neutrality, considered as an indicator of stress, in order to evidence the stations likely affected by some disturbance factor. Fishing impact (i.e. frequency of lost fishing gears) and damage on colonies as frequencies percentages were evaluated. Data were arcsin transformed, checked with Cochran's test and analysed with Anova and SNK Test, choosing p<0.01 as basal level of significance.

2.4. Coralligenous Structural Complexity of Assemblages

In order to evaluate the complexity of coralligenous assemblages we aggregated data into categories particularly sensitive to multiple stressors. These categories generally reply with the modulation of their actual structural features, from here defined as Structural Descriptors. We consider: α nude substratum (NS); β non-crustose coralline algae (nCCA); γ crustose coralline algae (CCA); δ encrusting/basal fauna (EPI I); ε massive epibenthic fauna (EPI II); ζ branching epibenthic fauna (EPI III).

Aggregated data were analysed with PERMANOVA, Principal coordinates analysis (PCO), with Spearman correlation > 0.2 and Similarities Percentages (SIMPER) Analysis. Frequencies percentage of the groups in each site are shown in graphics as means standard errors. Finally, the value of each Structural Descriptor (X, α... ζ) was calculated as the ratio between the sum of proportion of covering of the taxa included in each descriptor and the total covering of the community (tot) as:

X, α... ζ = (Σ π x α ... ζ)/tot

Since all descriptors ranged from 0 to 1, we divided them into 6 classes (α=0, 0< α <0.2 , 0.2< α <0.4, 0.4< α <0.6, 0.6< α <0.8, 0.8< α <1) assigning to

8

each class a score between 0 and 5.

The scores obtained from Structural Descriptors were combined in order to obtain a unique Index of 3D - Structural Complexity for the stations, as following:

$$3D\ C\text{-}index = \sum(d_\alpha + s\,d_\beta + s^2 d_\gamma + s^3\,d_\delta + s^4 d_\varepsilon + s^5\,d_\zeta)\,/5s^i \quad = \sum_{i=0}^{5} s^i d_i / \Sigma\,5s^i$$

Where

- i = the number of descriptors

- d = scores obtained for each i-th descriptor

- s = number of scores used to range descriptors

The method merges the structural descriptors weighting the scores obtained from the range values of such descriptors (   ).. It achieves a unique 3D - Structural Complexity Index, ranging between 0 and 1, and avoiding that the same Indexs value or similar values are obtained for multiple configurations. 3D Structural Index was calculated for each assemblage (shown in graphics as means ± SE) and analysed with Permutational Anova and Pair-wise tests on Euclidean distances calculated on square root transformed data, with unrestricted permutation of raw data (9999 permutations).

3. Results

3.1. Species analysis

The analysis of video-transects allowed identifying 28 taxa regarding plants and algae and 97 considering the fauna. These included 9 species of Chlorophyceae, 6 species belonging to Phaeophyceae, 9 species of Rhodophyceae and Posidonia oceanica for Monocotyledoneae. Concerning animal taxa, 26 species were identified among Porifera, 26 species among Cnidaria, 9 species of Mollusca, 6 species among Crustacea, 6 species of Bryozoa, 8 species of Polychaeta, 11 species among Echinodermata and 6 species of Tunicata. PCO analysis ordinated samples in the Euclidean space by evidencing the two axes that explain

9

the highest percentages of variation and relationships of considered categories across the plot, where length and directions of each vector indicates respectively strength and sign of relationship between variables and axes. The visual analysis of covering of species (Figure 2) showed a high spatial heterogeneity of samples among stations and low portions of variability was explained by the first two PCO axes (23,8% and 13,2 %,respectively). The ordination of samples showed dispersion and segregation for S. Stefano shoal stations. Closed to this latter and roughly overlapping appeared Santa Croce (SSCr) and Punta ManaraPM and the two stations of Gallinara (GS, GF), with correlation to Algal felt. Closed to S. Stefano La Luna (SSLu) and Canyon (SSCa) and diverging from the other stations, appeared the stations of Portofino, with overlapping among stations and clustering especially for Sector 3 (PTF3), with correlation with Inorganical detrital substratum, P. clavata, Lythophyllum fasciculatum and Leptosamnia pruvotii. Another group is represented by Tor PaternoTP, PapaTVP 1 and PapaTVP 2, these latter more clustered but all not so segregated and correlated to Udotea petiolata, solitary madrepores, empty tubes and Peyssonellia sp.. In contrast to samples of the other stations that appeared quite dispersed, the stations of PortofinoTavolara, PapaTVP 1 and 2 resulted more clustered, with the best fit for Portofino sectPTF 3. Besides the high variability evidenced, the comparison among assemblages of the 13 stations showed differences among all surveyed stations (PERMANOVA, P = 0.0001; Pair-wise Tests, P = 0.0001). The Analysis of Similarity Percentages performed at different taxa levels (Table 2) evidenced the species or groups mainly contributing to the variability of the stations, with frequencies percentages representing species/groups contributions.

3.2. Diversity analysis, anthropic pressure and damage of colonies

The variability in the composition resulted in the Diversity Analysis of the stations (Figure 3). The analysis highlighted differences among stations (PERMANOVA, P=0.0001), with significant differences among all stations (P<0.001), lower difference between SSLu and SSCa (P=0.0209) and TP (P=0.457), while

10

similar values were found between SSCC and GS, SSCr and PM, and PTF1 and PTF2. In particular differences among stations were found in species richness (PERMANOVA, P=0.0001), with TVP stations showing richness similar and higher than PTF3 (P=0.0036) and all the other stations (P=0.0001), followed by the other two stations of Portofino PTF1 and PTF2 (P<0.01). Lower than PTF were evidenced values of S Stefano SSLu, SSCa, PM, SSCr and TP (P<0.001) and then the stations of Gallinara (GF and GS) and SSCC, this latter with the lowest species richness (P=0.0001). Differences were evidenced in diversity (PERMANOVA, P=0.0001) and evenness too (PERMANOVA, P=0.0001). The site of TVP1 was the most diverse of all (P=0.0001), followed by TVP2, PTF3 (P<0.05) and PTF1and PTF2, SSLu, TP and GF, with similar values. Finally we evidenced SSCr, PM and the lowest diversity at SSCC and GS, values similar and lower respect to all the others (P<0.05). Equitability was higher in SSLu, PTF, TVP, TP and GF (P<0.05), while lower values were evidenced at SSCa, SSCC, GS, SSCr and PM (P<0.05). Caswells V Statistic highlighted that greater diversity was found in TVP stations, PTF1 and PTF3, TP and SSLu, whilst lower diversity was found in SSCa and SSCC, PTF2 and GS. Significant departure from neutral model was evidenced for SSCr, PM and GS, whose levels evidenced stress conditions. The analysis of fishing impact (Figure 3 a) evidenced differences in anthropic pressure among stations (Anova, P=0.0000). In particular for Portofino sect 2 we found the highest value (6,08%) of all stations (SNK, P<0.01), followed by similar values of Portofino sect 3, Gallinara Falconara (SNK, P<0.01) and lowest values of TVP2, TP and GS (SNK, P<0.01). Damaged colonies were evidenced for P.clavata and E. cavolini (Fig. 4 b, c). In particular the highest values (13.62 %) of damage of 1/3 of P. clavata were evidenced in TVP 2 (SNK, P<0.01), followed by lower and similar values in TVP1 and TP (SNK, P<0.01), while lower values were found in SSCa and PTF2 (SNK, P<0.01). Damage of 2/3 of colonies were highest (12.32%) in TVP1 (SNK, P<0.01), while lower values were evidenced at TP, SSCa and Portofino (SNK, P<0.01). Damage of 3/3 of colonies showed low and similar values in Portofino, TVP1 and SSCa. Also E. cavolini showed differences in level

11

of damage among stations (Anova, P=0.0056). In particular damage of 1/3 and

2/3 of colonies was evidenced without differences in the stations of TVP1, TP and Portofino, while TVP1 showed higher values of damage of 3/3 of colonies respect to PTF3 (SNK, P<0.01). In all cases damage showed always values lower than 1%.

3.3. Coralligenous Structural Complexity of Assemblages

Analysis performed considering the Structural Descriptors highlighted a strong correlation of roughly all segregated stations with branching fauna and less strength with encrusting and massive fauna, with exception of SSCC, whose samples appeared separated from the main clustered group and strongly correlated to nude substratum and crustose coralline algae (Figure 5). We evidenced differences in abundance among all stations (PERMANOVA, P=0.0001, ;Pair-wise Tests, P = 0.0001) of Nude Substratum (NS), Crustose Coralline Algae (CCA), non Crustose Coralline Algae (nCCA), encrusting fauna (EPI I), massive fauna (EPI II) and branching fauna (EPI III).The Similarity Percentages Analysis evidenced the characteristic groups for each site (Table 2) and this characterization resulted in a different composition of the community assemblages in each site (Figure 6). SSLu resulted to be characterized mainly by massive fauna, coralline algae with similar values and lower encrusting fauna (P<0.01). SSCa resulted characterized by a high cover percentage of branching fauna (P<0.01), non-crustose coralline algae and lower massive and encrusting fauna (P<0.01). The site of SSCC was mainly characterized by higher cover percentage of nude substratum (P<0.01) and coralline algae, with similar values. The site of SSCr resulted composed mainly by non-crustose coralline algae, higher than all others (P<0.01), and similar values of massive and encrusting fauna. Also the site of PM was characterized principally by non-crustose coralline algae, higher than all others (P<0.01), followed by similar values of massive fauna and crustose coralline algae and encrusting fauna. In the site of PTF1 were evidenced branching fauna, with percentage similar to nude substratum and higher than crustose coralline algae (P<0.01) and

12

similar values of massive fauna and non-crustose coralline algae. In the site

of PTF2 were evidenced massive and branching fauna, crustose coralline algae and encrusting fauna, with similar values. PTF3 was characterized by massive fauna, similar to nude substratum and branching fauna, higher than crustose coralline algae(P<0.01) and lower encrusting fauna (P<0.01). TVP1 resulted to be composed mainly by non-crustose coralline algae, higher than all

the others (P<0.01), similar values of crustose coralline algae, massive fauna, branching one and lower encrusting fauna (P<0.01), while TVP2 resulted characterized by higher crustose coralline algae (P<0.01), massive fauna similar to encrusting one and higher than non-crustose coralline algae (P<0.01). The site of TP resulted characterized by crustose coralline algae, similar to branch-

ing fauna, non-crustose coralline algae and lower encrusting fauna (P<0.01). Gallinara Falconara (GF) was characterized by higher crustose coralline algae (CCA)(P<0.01), similar nude substratum and non-crustose coralline algae, massive and encrusting fauna, while Gallinara Sciuscia (GS) resulted composed for highest contribution by non-crustose coralline algae (P<0.01), massive fauna

and lower branching one (P<0.01). The nude substratum was therefore prevalent in the site of SSCC. Non crustose coralline algae were dominant in SSCr, PM and GS, with low contributions of the other structural groups, while lower contributions of nCCA together with higher contributions of the other structural groups were found in TVP1. Crustose Coralline Algae were dominant in

TVP 2, TP and GF. Massive fauna resulted the most contributor in the site of SSLu, with high contributions of algae and basal fauna and with increasing frequencies from the site of PTF2 and PTF3, these latter characterized also by branching fauna. Branching fauna was dominant in PTF1, with low values of the other groups and with the highest contributions in the site of SSCa. The

Structural Descriptors differently characterized the stations, lending in each site a peculiar configuration of the structure of the communities composition that describes the coralligenous system. The peculiarities in the structure of the community composition of the coralligenous assemblages were expressed through a 3D-Coralligenous Index, with valuesranged between 0 (lowest complexity) and

1 (highest complexity), for each site in exam, showed in Table 3 and Figure 7 3D-Coralligenous Index evidenced differences among stations (PERMANOVA, P=0.0001) and in particular Pair-wise Tests evidenced SSCa as the site with the highest Structural Complexity, higher than PTF1 (P=0.02007), TP (P=0.0054) and all the other stations (P=0.0001), followed by Portofino PTF1-2-3 and TP. The lowest values were obtained by GF and SSCC (P=0.0001).

4. Discussion

The increasing attention towards the urgency to find shared methodolgies to assess health conditions of coralligenous assembalges has been highlighted by several international symposia focused on this topic (UNEP-MAP-RAC/SPA, 2009; 2014). In 2011 a list of categories of species to be considered in the inventory and/or monitoring of coralligenous communities was provided by UNEP-RAC/SPA (2011): Algal builders, Animal builders, Agglomerative animals, bioeroders, Species of particular importance (particularly abundant, sensitive, architecturally important or economically valuable), Invasive species. Since different regions and areas within regions are characterized by different composition and the heterogeneity is strongly related to the scale of observation, the assessment of coralligenous based on the above-mentioned morpho-functional categories list may simplify the way to find the coralligenous patterns across the Mediterranean. Taking into account this approach, the list here proposed selects categories considering the effects that several stressors can play on the physical complexity of coralligenous assemblages, clearly affecting the coralligenous ecosystem functioning. To have a shared and common list of simplified categories to consider for quick assessments can offer an good comparative basis towards a general view on Mediterranean coralligenous assemblages. This approach provides a functional perspective, focusing on indicators easily detectable through the analysis of video recording. The recording of videotransects allows to develop a quick methodology both during the underwater workphase and at the lab, avoiding the huge effort to recognize species in the different frames.

14

This appraoch is successful for the monitoring of the Good Envrionmental Status (GES) within the Marine Strategy Framework Directive requirements and COP18 EcAp Decision. Our results confirm the high spatial variability of coralligenous assemblages especially at a small-scale [21, 87, 82, 68]. In this work 13 stations along Italian coasts of Mediterranean Sea were studied by analysis of video-transects to verify the presence and abundance of 28 taxa of algae and 97 taxa of animals. Algae and Cnidaria resulted the main categories to characterize coralligenous assemblages, in particular Phaeophyceae, Chlorophyceae, Plexauridae and Scleractinia. Comparing the richness and diversity of the studied stations, TVP1 and TVP2 were found to be the most rich in species and the most diverse, while SSCC was the less rich and diverse. TVP1 and TVP2, Portofino (PTF1-2-3) and GF were found as the stations with the highest equitability, while stress conditions (according to [22]s neutral model) was evidenced in SSCr, PM and GS. Lost fishing gears were detected for half of the 13 stations and in particular fishing impact was higher in PTF2 with values around than 10%, while minor damage of colonies was evidenced for *P. clavata* in TVP stations with values close to the 10%. According to the intermediate disturbance hypothesis [29], species diversity is low where disturbance is minimal because of competitive exclusion between species, with relaxed competition and increased diversity in increased levels of stress, while with high level of disturbance species became eliminated by stress with downfall of diversity, underlining that diversity is highest in intermediate levels of disturbance, due to biotic or abiotic factors. Threatening of coralligenous communities due to abrasive activities acts primarily on the external layer and then on the underlying layers, reducing the number of dominant species, leading to the fragmentation of the community structure and creating niches for new pioneer and /or opportunistic species, so maintaining high biological diversity, but causing deep changes in the population diversity. A multidisciplinary approach has been attempted to studies marine stations considering parameters such as vulnerability, aesthetic or rarity values, addressing both biological and geomorphological aspects and to combine them in a synoptic view [73]. On both terrestrial and marine habi-

15

tats (e.g. forests, coral reefs, rocky intertidal, mangrove), the habitat structures have a strong influence on the diversity and abundance of species [8], confirming the role of topography in the distribution of the biodiversity. Habitat structure can be defined by structural complexity, scale and heterogeneity [58] and structural complexity of substrata, measured by relief, interstitial space and surface area [45, 9], can be named as topographic complexity, roughness or substrate heterogeneity [58] . Many techniques [89] and indexes have been proposed to study how substrata affect density and diversity of species and to make comparison within habitats [58, 33]. Conversely, measurement of substrata complexity are related to the scale of observations, size and arrangement of organisms to compare habitats [8, 11, 92] and difficulties are related to the comparability of indices between habitats and scales [58]. Moreover condensing substrata complexity into single measures may lead to a great loss of information [80] and habitat complexity and benthic composition can be reliably estimated visually [89]. Small scale topographical heterogeneity is considered the cause of patch distribution, influencing recruitment and offering suitable refuges and microhabitats with different physical conditions [3, 51, 88], suitable for a particular high faunal diversity [52]. In coralligenous assemblages competition for space represents one of the main processes determining patterns of distribution of the system, in which crustose organisms compete intensely for substratum because of the limited use of space in two dimensions [20] and this process could concur to increase patchiness. Predation pressure, which can limit diversity [59], is furthermore reduced in semi-enclosed microhabitats [52]. An important consideration refers to correlation of ecological status of coralligenous assemblages of Mediterranean coasts to human pressure. In tropical areas, [35] analysed the responses of reef assemblages to modifications in environmental parameters caused by terrestrial pressure. Besides these approaches, in this work together with all analysis performed at species level, we proposed a method to assess the complexity of the assemblages composing the coralligenous systems, taking into consideration different groups of organisms, named here Structural Descriptors, that describe the structural complexity of the community. A different compo-

sition of the assemblages was therefore evidenced not only at species level, but evaluating the whole coralligenous assemblage. The methods allowed us to evidence some patterns in the structure of assemblages, that could probably let hypothesize a succession in coralligenous structuring, from dominance of nude substratum towards dominance of branching fauna that could represent a climax in coralligenous habitat, with the highest expected tridimensionality. The method finally allowed us to assess a measure of 3D-Complexity Structure for the habitat of coralligenous, based on quantitative covering data of species analysed by video-transects, combining the individuated Structural Descriptors in order to obtain a unique Index of 3D - Structural Complexity ranged between 0 and 1 and avoiding that the same indexs value or similar values are obtained by multiple configurations, as occurs obtaining the sum of metrics. Up today many proposed indexes deals with the ecological status assessment of the coralligenous system, from medium depth to the mesophotic assemblages, based on choosen metrics, combined by sum [41, 33, 19]. Moreover, the proposed method of evaluation takes in consideration not only some choosen metrics, but all organisms composing the coralligeous system, all with their own coverage contemplating also the situation where only substratum is present. The proposed method of evaluation of structural complexity of coralligenous assemblages could moreover be suited as a procedure to more rapidly and easily analyse assemblages, giving the possibility to collect data not only strikingly on singles species, but directly on the groups of organisms identified by Structural Descriptors, even without taxonomical specialization. It will allow us to use such information as baselines for monitoring over time the coralligenous systems and to detect eventual loss in complexity of the communities. Further investigations are needed in order to confirm the role of branching fauna as ecosystem engineer in coralligenous accretions. All efforts addressed to the knowledge of coralligenous accretions will constitute the baseline for environmental protection programs. The variability of habitats present at S Stefano, from P. oceanica meadow and detritic to sandy bottoms, to vertical cliffs of coralligenous rims more exposed to current flows, allowed us to evidence here different levels of structural complexity, from the

17

low one due to the high presence of nude substratum in Croce Cappello (SSCC), to the highest structural complexity due to the presence of branching fauna at SSCa. The high presence of non-crustose coralline algae in SSCr, PM and GS, as of coralline algae in GF, but however with strong presence of nude substratum and non-crustose coralline algae, could be justified by their heterogeneity of the bottom, strongly composed by P. oceanica meadow and sandy-muddy bottom, that could prevent the settlement of a more structured coralligenous community. Although a more structured coralligenous was represented in TVP1 respect to the previously mentioned stations, non-crustose coralline algae were also here strongly present, probably due to a high light availability that at this site facilitate the colonisation of photophylous algae, while a lower one at the other site of Tavolara (TVP) probably enhanced the development of a more sciaphilous community. Crustose coralline algae were dominant also at TP, but a stronger presence also of branching fauna increase the three-dimensionality of the bottom. Basal and massive fauna, together with a strong presence of branching one, characterized instead Portofino, with a well-structured coralligenous community evidenced in a very rich rocky substratum. Finally, the highest dominance of branching fauna at SSCa lead to the highest three-dimensional coralligenous community. Besides the highest richness and diversity evidenced at Tavolara and Portofino, where we showed respectively damaged colonies and fishing impacts, a lower richness and diversity but the highest three-dimensionality of coralligenous structure was found at SSCa. This could be due to the vertical cliff and the exposure to current flows that could be key conditions here for the establishment of a more rich branching fauna population. These evidences could justify differences in fauna also along the same stretch of the shelf [46, 72] providing more complex habitats and effects on circulation. The high topographic complexity could therefore support a high structural complexity of the assemblages, in terms of three-dimensionality of the community, measured for the first time in this work. Moreover canyons concentrate sediment rich in organic detritus providing trophic resources for suspension-feeders [36]. The availability of nutritive particles in suspension by current flows and controlling of resuspen-

18

sion and sediment rates by cascading processes, seems to greatly influence coral distributions [18, 32]. Despite the stability of coralligenous habitats [66, 39] , destructive events such as mass mortalities can strongly affect the coralligenous community [81, 25, 49, 38]. While impacts due to fishing are diluted in time but very marked, altering density and size of the structuring epibenthic organisms [85] and the recovery is quite unlikely [7], phenomena of mass mortalities are usually of acute intensity even if occasional and a possible recovery can occur [53, 31, 23]. The resistance and the resilience of the community depend on its health status, leading to even local extinction of entire populations in case of already impacted communities, or to a fast and complete recovery of the community in previous healthy situation [49, 60]. This underlines the importance of ancient baseline or historical data to actually estimate the magnitude of change of the coralligenous assemblages and therefore estimate a state of relative health. Anthropic activities and climatic changes cause modifications of environmental parameters and indirectly on organisms, populations and communities, leading to the necessity to improve the knowledge in the composition and distribution of populations, their viability and reaction towards natural or anthropic stresses finalized to the creation of datasets as the starting point for a spatial and temporal monitoring. Physical human impacts, climate change, acidification, and pollution deeply influence coralligenous assemblages [48, 15, 27, 26, 50], maintained by the balance between bio-construction and bio-erosion, very sensitive to environmental changes [78, 37].

Acknowledgements

....

References

[1] Airoldi, L., Rindi, F., Cinelli, F., 1995. Structure, seasonal dynamics and reproductive phenology of a filamentous turf assemblage on a sediment influenced, rocky subtidal shore. Botanica marina 38 (1-6), 227–238.

19

[2] Anderson, M. J., 2001. A new method for non-parametric multivariate analysis of variance. Austral ecology 26 (1), 32–46.

[3] Archambault, P., Bourget, E., 1996. Scales of coastal heterogeneity and benthic intertidal species richness, diversity and abundance. Marine Ecology Progress Series 136, 111–121.

[4] Ballesteros, E., 2006. Mediterranean coralligenous assemblages: A synthesis of present knowledge (in Oceanography and marine biology: An annual review-Volume 48, pp. 123-195).

[5] Ballesteros, E., Sala, E., Garrabou, J., Zabala, M., 1998. Community structure and frond size distribution of a deep water stand of Cystoseira spinosa (Phaeophyta) in the Northwestern Mediterranean. European journal of phycology 33 (02), 121–128.

[6] Bavestrello, G., Bianchi, C., Calcinai, B., Cattaneo-Vietti, R., Cerrano, C., Morri, C., Puce, S., Sara, M., 2000. Bio-mineralogy as a structuring factor for marine epibenthic communities. Marine Ecology Progress Series 193, 241–249.

[7] Bavestrello, G., Cerrano, C., Zanzi, D., Cattaneo-Vietti, R., 1998. Damage by fishing activities to the Gorgonian coral Paramuricea clavata in the Ligurian Sea. Oceanographic Literature Review 3 (45), 543.

[8] Beck, M. W., 1998. Comparison of the measurement and effects of habitat structure on gastropods in rocky intertidal and mangrove habitats. Marine Ecology Progress Series 169, 165–178.

[9] Beck, M. W., 2000. Separating the elements of habitat structure: independent effects of habitat complexity and structural components on rocky intertidal gastropods. Journal of Experimental Marine Biology and Ecology 249 (1), 29–49.

[10] Bedini, R., Bonechi, L., Piazzi, L., 2014. Spatial and temporal variability of mobile macro-invertebrate assemblages associated to coralligenous habitat. Mediterranean Marine Science 15 (2), 302–312.

[11] Bell, S. S., Brooks, R. A., Ellis, W. E., 2003. Structural spacing and the determination of habitat complexity: examining the Bartholomew et al.(2000) index. Marine Ecology Progress Series 248, 293–295.

[12] Bertolino, M., Cerrano, C., Bavestrello, G., Carella, M., Pansini, M., Calcinai, B., 2013. Diversity of Porifera in the Mediterranean coralligenous accretions, with description of a new species. ZooKeys 336, 1.

[13] Bianchi, C., Cattaneo-Vietti, R., Morri, C., Navone, A., Panzalis, P., Orru, P., 2007. Coralligenous formations in the Marine Protected Area of Tavolara Punta Coda Cavallo(N-E Sardinia, Italy). Biologia marina mediterranea 14 (2), 148–149.

[14] Boudouresque, C.-F., 1990. Livre rouge" Gérard Vuignier" des végétaux, peuplements et paysages marins menacés de Méditerranée. No. 43. PNUE, Aires Spécialement Protégées.

[15] Bourcier, M., 1986. Évolution, en cinq années, des herbiers à Posidonia oceanica et du macrobenthos circalittoral action conjuguée des activités humaines et des modifications climatiques. Vie et milieu 36 (1), 1–8.

[16] Calcinai, B., Bertolino, M., Bavestrello, G., Montori, S., Mori, M., Pica, D., Valisano, L., Cerrano, C., 2015. Comparison between the sponge fauna living outside and inside the coralligenous bioconstruction. A quantitative approach. Mediterranean Marine Science 16 (2), 413–418.

[17] Calvisi, G., Trainito, E., Pais, M., Franci, G., Schiaparelli, S., 2003. Prima segnalazione di un episodio di mortalitadi gorgonacei lungo la costa dell'Isola di Tavolara (Sardegna Settentrionale). Biologia Marina Mediterranea 10 (2), 506–508.

21

[18] Canals, M., Puig, P., de Madron, X. D., Heussner, S., Palanques, A., Fabres, J., 2006. Flushing submarine canyons. Nature 444 (7117), 354–357.

[19] Cánovas-Molina, A., Montefalcone, M., Bavestrello, G., Cau, A., Bianchi, C. N., Morri, C., Canese, S., Bo, M., 2016. A new ecological index for the status of mesophotic megabenthic assemblages in the mediterranean based on ROV photography and video footage. Continental Shelf Research 121, 13–20.

[20] Carpenter, R. C., 1990. Competition among marine macroalgae: a physiological perspective. Journal of Phycology 26 (1), 6–12.

[21] Casas-Güell, E., Teixidó, N., Garrabou, J., Cebrian, E., 2015. Structure and biodiversity of coralligenous assemblages over broad spatial and temporal scales. Marine Biology 162 (4), 901–912.

[22] Caswell, H., 1976. Community structure: a neutral model analysis. Ecological monographs 46 (3), 327–354.

[23] Cerrano, C., Arillo, A., Azzini, F., Calcinai, B., Castellano, L., Muti, C., Valisano, L., Zega, G., Bavestrello, G., 2005. Gorgonian population recovery after a mass mortality event. Aquatic Conservation: Marine and Freshwater Ecosystems 15 (2), 147–157.

[24] Cerrano, C., Bavestrello, G., Bianchi, C., Calcinai, B., Cattaneo-Vietti, R., Morri, C., Sarà, M., 2001. The role of sponge bioerosion in Mediterranean coralligenous accretion. In: Mediterranean Ecosystems. Springer, pp. 235–240.

[25] Cerrano, C., Bavestrello, G., Bianchi, C., Cattaneo-Vietti, R., Bava, S., Morganti, C., Morri, C., Picco, P., Sara, G., Schiaparelli, S., et al., 2000. A catastrophic mass-mortality episode of gorgonians and other organisms in the Ligurian Sea (North-western Mediterranean), summer 1999. Ecology letters 3 (4), 284–293.

[26] Cerrano, C., Cardini, U., Bianchelli, S., Corinaldesi, C., Pusceddu, A., Danovaro, R., 2013. Red coral extinction risk enhanced by ocean acidification. Scientific reports 3, 1457.

[27] Cinelli, F., Balata, D., Piazzi, L., 2007. Threats to coralligenous assemblages: sedimentation and biological invasions. In: Proceedings of the 3rd Mediterranean Symposium on Marine Vegetation, Marseille, France. pp. 27–29.

[28] Coma, R., Linares, C., Pola, E., Zabala, M., 2001. Seguiment temporal de la gorgonia Paramuricea clavata de les illes Medes. Exercici 2001. Seguiment temporal de l'àrea marina protegida de les illes Medes. Informe anual any, 59–82.

[29] Connell, J. H., 1978. Diversity in tropical rain forests and coral reefs. Science 199 (4335), 1302–1310.

[30] Costantini, F., Rossi, S., Pintus, E., Cerrano, C., Gili, J.-M., Abbiati, M., 2011. Low connectivity and declining genetic variability along a depth gradient in corallium rubrum populations. Coral reefs 30 (4), 991–1003.

[31] Cupido, R., Cocito, S., Manno, V., Ferrando, S., Peirano, A., Iannelli, M., Bramanti, L., Santangelo, G., 2012. Sexual structure of a highly reproductive, recovering gorgonian population: quantifying reproductive output. Marine Ecology Progress Series 469, 25–36.

[32] DeGeest, A., Mullenbach, B., Puig, P., Nittrouer, C., Drexler, T. M., de Madron, X. D., Orange, D., 2008. Sediment accumulation in the western Gulf of Lions, France: the role of Cap de Creus canyon in linking shelf and slope sediment dispersal systems. Continental Shelf Research 28 (15), 2031–2047.

[33] Deter, J., Descamp, P., Ballesta, L., Boissery, P., Holon, F., 2012. A preliminary study toward an index based on coralligenous assemblages for the

ecological status assessment of Mediterranean French coastal waters. Ecological indicators 20, 345–352.

[34] European Community, 22-12-2000. Council Directive for a legislative frame and actions for the water policy, 2000/60/EC. Tech. rep., European Community.

[35] Fabricius, K. E., 2005. Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. Marine pollution bulletin 50 (2), 125–146.

[36] Garcia, R., Van Oevelen, D., Soetaert, K., Thomsen, L., De Stigter, H., Epping, E., 2008. Deposition rates, mixing intensity and organic content in two contrasting submarine canyons. Progress in Oceanography 76 (2), 192–215.

[37] Garrabou, J., Ballesteros, E., 2000. Growth of Mesophyllum alternans and Lithophyllum frondosum (Corallinales, Rhodophyta) in the northwestern Mediterranean. European Journal of Phycology 35 (1), 1–10.

[38] Garrabou, J., Coma, R., Bensoussan, N., Bally, M., Chevaldonné, P., Cigliano, M., Díaz, D., Harmelin, J.-G., Gambi, M. C., Kersting, D., et al., 2009. Mass mortality in Northwestern Mediterranean rocky benthic communities: effects of the 2003 heat wave. Global change biology 15 (5), 1090–1103.

[39] Garrabou, J., Kipson, S., Kaleb, S., Kružić, P., Jaklin, A., Žuljević, A., Rajković, v., Rodić, P., Jelić, K., Župan, D., 2015. Monitoring protocol for coralligenous community.

[40] Garrabou, J., Sala, E., Arcas, A., Zabala, M., 1998. The impact of diving on rocky sublittoral communities: a case study of a bryozoan population. Conservation Biology 12 (2), 302–312.

[41] Gatti, G., Montefalcone, M., Rovere, A., Parravicini, V., Morri, C., Albertelli, G., Nike Bianchi, C., 2012. Seafloor integrity down the harbor

waterfront: the coralligenous shoals off Vado Ligure (NW Mediterranean). Advances in Oceanography and Limnology 3 (1), 51–67.

[42] Georgiadis, M., Papatheodorou, G., Tzanatos, E., Geraga, M., Ramfos, A., Koutsikopoulos, C., Ferentinos, G., 2009. Coralligène formations in the eastern Mediterranean Sea: Morphology, distribution, mapping and relation to fisheries in the southern Aegean Sea (Greece) based on high-resolution acoustics. Journal of experimental marine biology and ecology 368 (1), 44–58.

[43] Giakoumi, S., Katsanevakis, S., Vassilopoulou, V., Panayotidis, P., Kavadas, S., Issaris, Y., Kokkali, A., Frantzis, A., Panou, A., Mavrommati, G., 2013. Could European marine conservation policy benefit from systematic conservation planning? Aquatic Conservation: Marine and Freshwater Ecosystems 22 (6), 762–775.

[44] Gower, J. C., 1966. Some distance properties of latent root and vector methods used in multivariate analysis. Biometrika 53 (3-4), 325–338.

[45] Grigg, R. W., 1994. Effects of sewage discharge, fishing pressure and habitat complexity on coral ecosystems and reef fishes in Hawaii. Marine ecology progress series. Oldendorf 103 (1), 25–34.

[46] Hecker, B., 1990. Variation in megafaunal assemblages on the continental margin south of New England. Deep Sea Research Part A. Oceanographic Research Papers 37 (1), 37–57.

[47] Hong, J.-S., 1980. Etude faunistique d'un fond de concrétionnement de typre coralligène soumis à un gradient de pollution en Méditerranée nord-occidentale (Golfe de Fos). Ph.D. thesis.

[48] Hong, J.-S., 1983. Impact of the Pollution on the Benthic Community Environmental impact of the pollution on the benthic coralligenous community in the Gulf of Fos, northwestern Mediterranean. Korean Journal of Fisheries and Aquatic Sciences 16 (3), 273–290.

[49] Huete-Stauffer, C., Vielmini, I., Palma, M., Navone, A., Panzalis, P., Vezzulli, L., Misic, C., Cerrano, C., 2011. Paramuricea clavata (Anthozoa, Octocorallia) loss in the Marine Protected Area of Tavolara (Sardinia, Italy) due to a mass mortality event. Marine Ecology 32 (s1), 107–116.

[50] LA, M. S., ET, C. D. C., BIO-CONCRÉTIONS, A., 2014. Proceedings of 2nd mediterranean symposium on the conservation of coralligenous and other calcareous bio-concretions.

[51] Lapointe, L., Bourget, E., 1999. Influence of substratum heterogeneity scales and complexity on a temperate epibenthic marine community. Marine Ecology Progress Series 189, 159–170.

[52] Le Hir, M., Hily, C., 2005. Macrofaunal diversity and habitat structure in intertidal boulder fields. Biodiversity & Conservation 14 (1), 233–250.

[53] Linares, C., Coma, R., Diaz, D., Zabala, M., Hereu, B., Dantart, L., 2005. Immediate and delayed effects of a mass mortality event on gorgonian population dynamics and benthic community structure in the NW Mediterranean Sea. Marine Ecology Progress Series 305, 127–137.

[54] Luna, B., Pérez, C. V., Sánchez-Lizaso, J. L., 2009. Benthic impacts of recreational divers in a Mediterranean Marine Protected Area. ICES Journal of Marine Science: Journal du Conseil 66 (3), 517–523.

[55] Martin, C., Giannoulaki, M., De Leo, F., Scardi, M., Salomidi, M., Knittweis, L., Pace, M., Garofalo, G., Gristina, M., Ballesteros, E., et al., 2014. Coralligenous and maërl habitats: predictive modelling to identify their spatial distributions across the Mediterranean Sea. Scientific Reports 4.

[56] Mateos-Molina, D., Palma, M., Ruiz-Valentín, I., Panagos, P., García-Charton, J. A., Ponti, M., 2015. Assessing consequences of land cover changes on sediment deliveries to coastal waters at regional level over the last two decades in the northwestern Mediterranean Sea. Ocean & Coastal Management 116, 435–442.

[57] McArdle, B. H., Anderson, M. J., 2001. Fitting multivariate models to community data: a comment on distance-based redundancy analysis. Ecology 82 (1), 290–297.

[58] McCoy, E. D., Bell, S. S., 1991. Habitat structure: the evolution and diversification of a complex topic. In: Habitat structure. Springer, pp. 3–27.

[59] Menge, B. A., 1976. Organization of the New England rocky intertidal community: role of predation, competition, and environmental heterogeneity. Ecological Monographs 46 (4), 355–393.

[60] Micheli, F., Saenz-Arroyo, A., Greenley, A., Vazquez, L., Montes, J. A. E., Rossetto, M., De Leo, G. A., 2012. Evidence that marine reserves enhance resilience to climatic impacts. PloS one 7 (7), e40832.

[61] MOKHTAR-JAMAÏ, K., Pascual, M., LEDOUX, J.-B., Coma, R., FÉRAL, J.-P., Garrabou, J., Aurelle, D., 2011. From global to local genetic structuring in the red gorgonian Paramuricea clavata: the interplay between oceanographic conditions and limited larval dispersal. Molecular Ecology 20 (16), 3291–3305.

[62] Navone, A., Bianchi, C., Orru, P., Ulzega, A., 1992. Saggio di cartografia geomorfologica e bionomica nel parco marino di Tavolara-Capo Coda Cavallo. Oebalia 17 (2), 469–478.

[63] Navone, A., Trainito, E., 2008. Tavolare: Nature at Work...Working in Nature. Delfino Carlo Editore & Co.

[64] Palanques, A., Guillén, J., Puig, P., 2001. Impact of bottom trawling on water turbidity and muddy sediment of an unfished continental shelf. Limnology and Oceanography 46 (5), 1100–1110.

[65] Pérès, J.-M., Picard, J., 1964. Nouveau manuel de bionomie benthique de la Méditerranée. Place of publication not identified.

[66] Piazzi, L., Gennaro, P., Balata, D., 2012. Threats to macroalgal coralligenous assemblages in the Mediterranean Sea. Marine Pollution Bulletin 64 (12), 2623–2629.

[67] Piazzi, L., Pardi, G., Balata, D., Cecchi, E., Cinelli, F., 2002. Seasonal dynamics of a subtidal north-western Mediterranean macroalgal community in relation to depth and substrate inclination. Botanica Marina 45 (3), 243–252.

[68] Ponti, M., Fava, F., Abbiati, M., 2011. Spatial–temporal variability of epibenthic assemblages on subtidal biogenic reefs in the northern Adriatic Sea. Marine biology 158 (7), 1447–1459.

[69] Ponti, M., Grech, D., Mori, M., Perlini, R. A., Ventra, V., Panzalis, P. A., Cerrano, C., 2016. The role of gorgonians on the diversity of vagile benthic fauna in Mediterranean rocky habitats. Marine Biology 163 (5), 1–14.

[70] Ponti, M., Perlini, R. A., Ventra, V., Grech, D., Abbiati, M., Cerrano, C., 2014. Ecological shifts in Mediterranean coralligenous assemblages related to gorgonian forest loss. PloS one 9 (7), e102782.

[71] Riedl, R., 1966. Biologie der Meereshöhlen: Topographie, Faunistik und Ökologie eines unterseeischen Lebensraumes; eine Monographie. Parey.

[72] Rogers, A., Billett, D., Berger, W., Flach, E., Freiwald, A., Gage, J., Hebbeln, D., Heip, C., Pfannkuche, O., Ramirez-Llodra, E., et al., 2002. Life at the edge: achieving prediction from environmental variability and biological variety. In: Ocean Margin Systems. Springer, pp. 387–404.

[73] Rovere, A., Parravicini, V., Firpo, M., Morri, C., Nike Bianchi, C., 2011. Combining geomorphologic, biological and accessibility values for marine natural heritage evaluation and conservation. Aquatic Conservation: marine and freshwater ecosystems 21 (6), 541–552.

28

[74] Sala, E., Garrabou, J., Zabala, M., 1996. Effects of diver frequentation on Mediterranean sublittoral populations of the bryozoan Pentapora fascialis. Marine Biology 126 (3), 451–459.

[75] Sarà, M., 1969. Research on coralligenous formations: problems and perspectives. Publ staz zool Napoli 37, 124–134.

[76] Sarà, M., Pulitzer-Finali, G., 1970. Nuove vedute sulla classificazione dei fondi coralligeni. Pubbl. Staz. Zool. Napoli 38 (Suppl II), 174.

[77] Sartoretto, S., 1996. Vitesses de croissance et de bioérosion des concrétionnements coralligènes de Méditerranée nord-occidentale. Rapport avec les variations holocènes du niveau marin. Ph.D. thesis.

[78] Sartoretto, S., Francour, P., 1997. Quantification of bioerosion by Sphaerechinus granularis on coralligene concretions of the western Mediterranean. Oceanographic Literature Review 10 (44), 1117–1118.

[79] Scinto, A., Bertolino, M., Calcinai, B., Huete-Stauffer, C., Previati, M., Romagnoli, T., Cerrano, C., 2009. Role of a Paramuricea clavata forest in modifying the coralligenous assemblages. Pergent-Martini C, Brichet M, editors, 15–16.

[80] Simberloff, D., Berthet, P., Boy, V., Cousins, S., Fortin, M.-J., Goldburg, R., Lefkovitch, L., Ripley, B., Scherrer, B., Tonkyn, D., 1987. Novel statistical analyses in terrestrial animal ecology; dirty data and clean questions. In: Develoments in Numerical Ecology. Springer, pp. 559–572.

[81] Teixidó, N., Casas, E., Cebrián, E., Linares, C., Garrabou, J., 2013. Impacts on coralligenous outcrop biodiversity of a dramatic coastal storm. PLoS One 8 (1), e53742.

[82] Terlizzi, A., Anderson, M. J., Fraschetti, S., Benedetti-Cecchi, L., 2007. Scales of spatial variation in Mediterranean subtidal sessile assemblages at different depths. Marine Ecology Progress Series.

[83] Torgerson, W. S., 1958. Theory and methods of scaling.

[84] Valisano, L., Notari, F., Mori, M., Cerrano, C., 2016. Temporal variability of sedimentation rates and mobile fauna inside and outside a gorgonian garden. Marine Ecology.

[85] Vezzulli, L., Colwell, R. R., Pruzzo, C., 2013. Ocean warming and spread of pathogenic vibrios in the aquatic environment. Microbial ecology 65 (4), 817–825.

[86] Vietti, R. C., Albertelli, G., Aliani, S., Bava, S., Bavestrello, G., Cecchi, L. B., Bianchi, C., Bozzo, E., Capello, M., Castellano, M., et al., 2010. The Ligurian Sea: present status, problems and perspectives. Chemistry and Ecology 26 (S1), 319–340.

[87] Virgilio, M., Airoldi, L., Abbiati, M., 2006. Spatial and temporal variations of assemblages in a Mediterranean coralligenous reef and relationships with surface orientation. Coral reefs 25 (2), 265–272.

[88] Walters, L. J., Wethey, D. S., 1996. Settlement and early post-settlement survival of sessile marine invertebrates on topographically complex surfaces: the importance of refuge dimensions and adult morphology. Marine Ecology Progress Series 137, 161.

[89] Wilson, S., Graham, N., Polunin, N., 2007. Appraisal of visual assessments of habitat complexity and benthic composition on coral reefs. Marine Biology 151 (3), 1069–1076.

[90] Zapata, M. A. B., Martinez-Guzman, W., Vargas-Ramirez, L., Herrera, K., Gonzalez-Garcia, M., 2015. Prevalence of central sleep apnea during continous positive airway pressure (CPAP) titration in subjects with obstructive sleep apnea syndrome at an altitude of 2640 m. Sleep medicine 16 (3), 343–346.

[91] Zapata-Ramírez, P., Scaradozzi, D., Sorbi, L., Palma, M., Pantaleo, U., Ponti, M., Cerrano, C., 2013. Innovative study methods for the Mediter-

ranean coralligenous habitats. Advances in Oceanography and Limnology 4 (2), 102–119.

[92] Zapata-Ramírez, P. A., Huete-Stauffer, C., Scaradozzi, D., Marconi, M., Cerrano, C., 2016. Testing methods to support management decisions in coralligenous and cave environments. A case study at Portofino MPA. Marine environmental research 118, 45–56.

Tables and Figures

Table 1: Surveyed stations

Sites	Longitude	Latitude
Secca di Santo Stefano (SS-Lu, -CC. -Ca, -Cr)	412658	4853221
Gallinara Island (GP, GS)	438276	4874941
AMP Portofino; Punta del Faro (PTF)	517408	4904983
Punta Manara (PM)	532264	4899424
AMP Tor Paterno (TP)	460946	278469
AMP Tavolara, Secche del papa (TVP)	562801	4529091

Table 2: Table of Similarity Percentages Analysis (SIMPER)

Site	Main current direction	MPA or other conservation measures	River proximity over-current	Exposure	Distance from towns (km)
SSLu	westward	No	6 km (Rio San Lorenzo)	east	0.5
SSCC	westward	No	13 km (Impero creek)	east	0.5
SSCa	westward	No		east	0.5
SSCr	westward	No		east	0.5
GF	westward	No	2 km (Centa River)	west	2
GS	westward	No		south	2
PTF1	westward	Yes	9 km (Entella River)	east	10
PTF2	westward	Yes		south	10
PTF3	westward	Yes		south	10
PM	westward	No	1.5 km (Gromolo creek)	south	2
TVP1	northward	Yes	19 km (Rio Siligheddu)	South-east	10
TVP2	northward	Yes		South-east	10
TP	northward	Yes	18 km (Tevere River)	North	10

Table 3: 3D Index of Coralligenous Complexity

3D C-Index	means	± SE
SSLu	0,057	0,005
SSCa	0,500	0,037
SSCC	0,031	0,009
SSCr	0,125	0,015
PM	0,059	0,011
PTF1	0,366	0,029
PTF2	0,288	0,015
PTF3	0,313	0,021
TVP1	0,256	0,014
TVP2	0,245	0,027
TP	0,346	0,024
GF	0,029	0,002
GS	0,048	0,004

Figure 1: Map of the studied stations. 1) Santo Stefano Shoal; 4 stations (SSCC, SSCa, SSLu, SSCr). 2) Gallinara Island; 2 stations (GF, GS). 3) Portofino MPA; 3 stations (PTF1, PTF2, PTF3). 4) Punta Manara (PM). 4) Tavolara Capo Coda Cavallo MPA; 2 stations (TVP1, TVP2). 5) Secche di Tor Paterno MPA; 1 Station (TP).
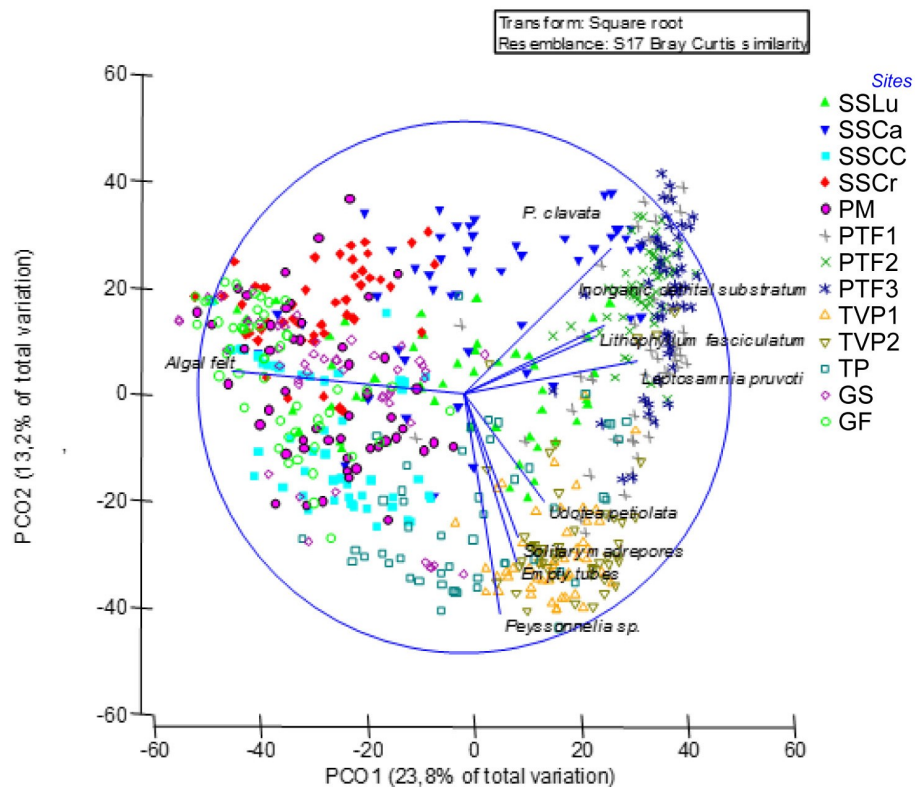
Figure 2: PCO ordination plot based on Bray-Curtis similarities of square root transformed percentage of species covering data in the 13 stations in exam. Vectors superimposed on the PCO plot represent Spearman correlation ¿ 0,5 of the most important groups with PCO axes.
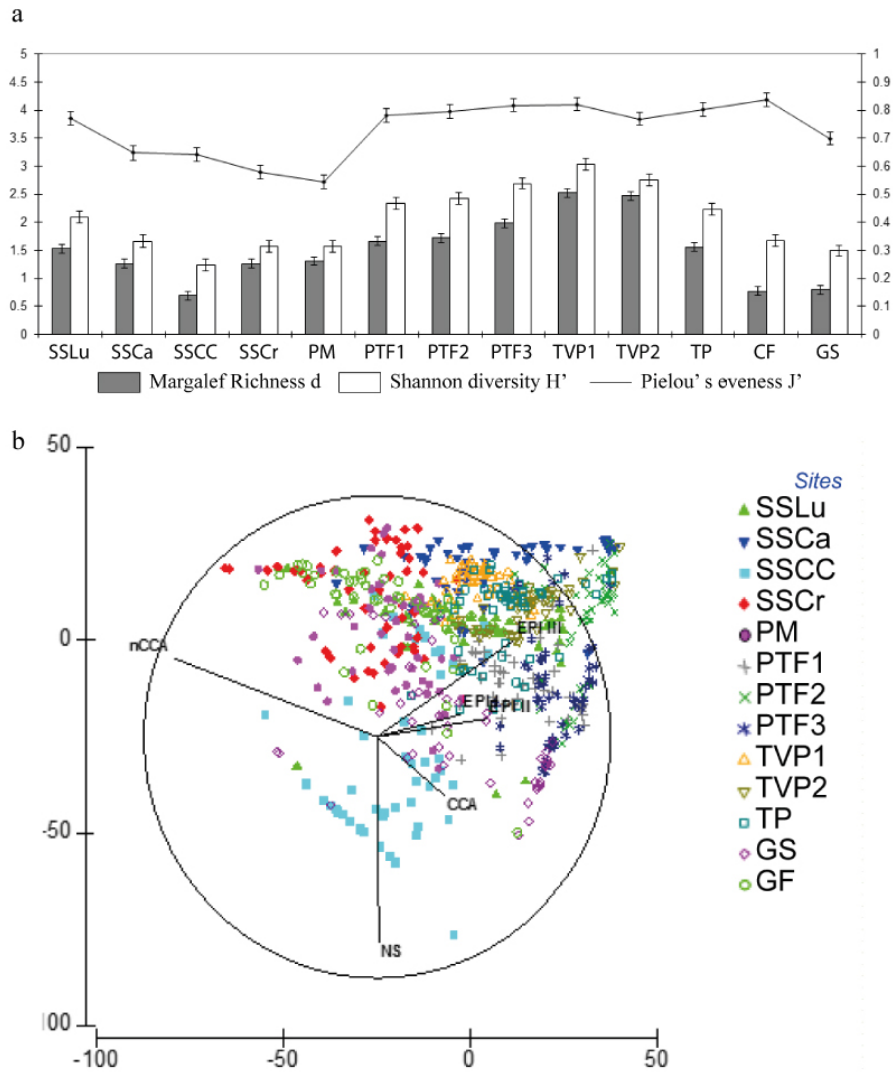
Figure 3: Diversity analysis (a) and PCA (b) of the stations in exam: Margalef richness d; Shannon diversity H(log2) and Pielou eveness J are indicated.
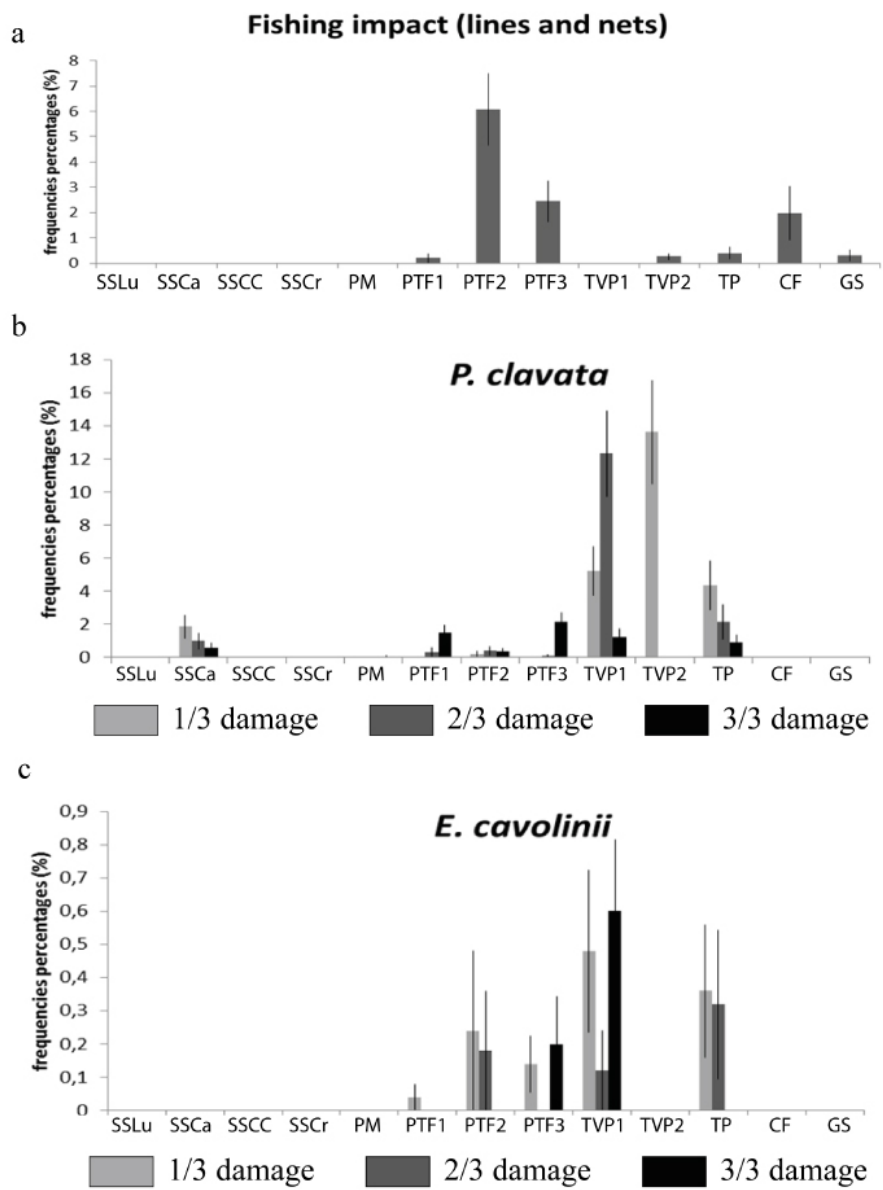
Figure 4: Frequencies percentages of anthropic pressure: fishing impact (lines and nets)(a) and damage on colonies of *P. clavata* (b) and *E. cavolinii (c)*.
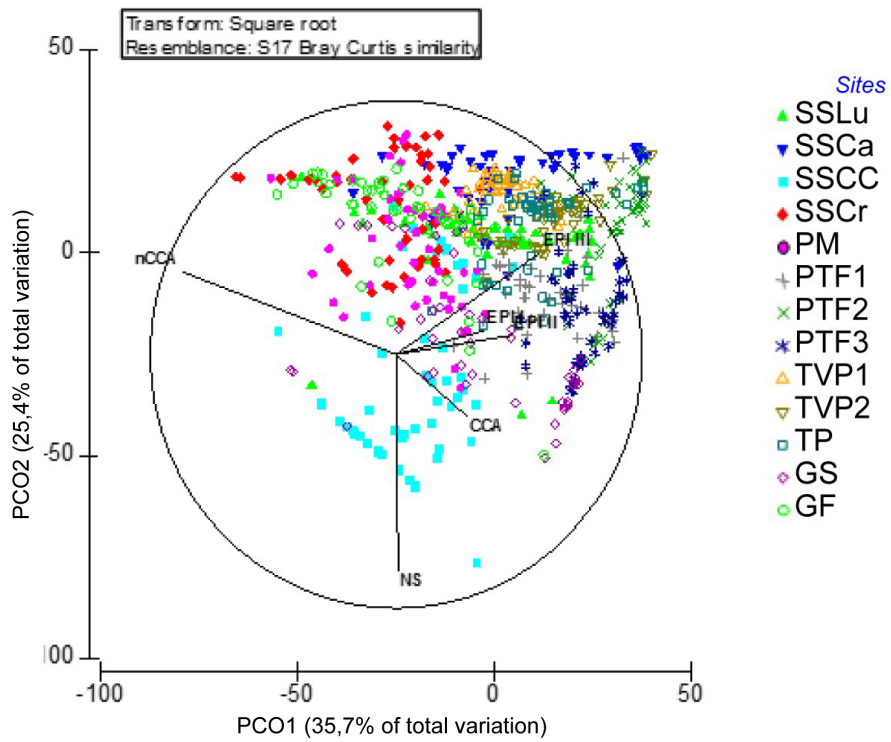
Figure 5: PCO ordination plot based on Bray-Curtis similarities of square root transformed percentage of covering data of groups structuring coralligenous assemblages in the 13 stations in exam. Vectors superimposed on the PCO plot represent Spearman correlation > 0.2 of the groups with PCO axes.
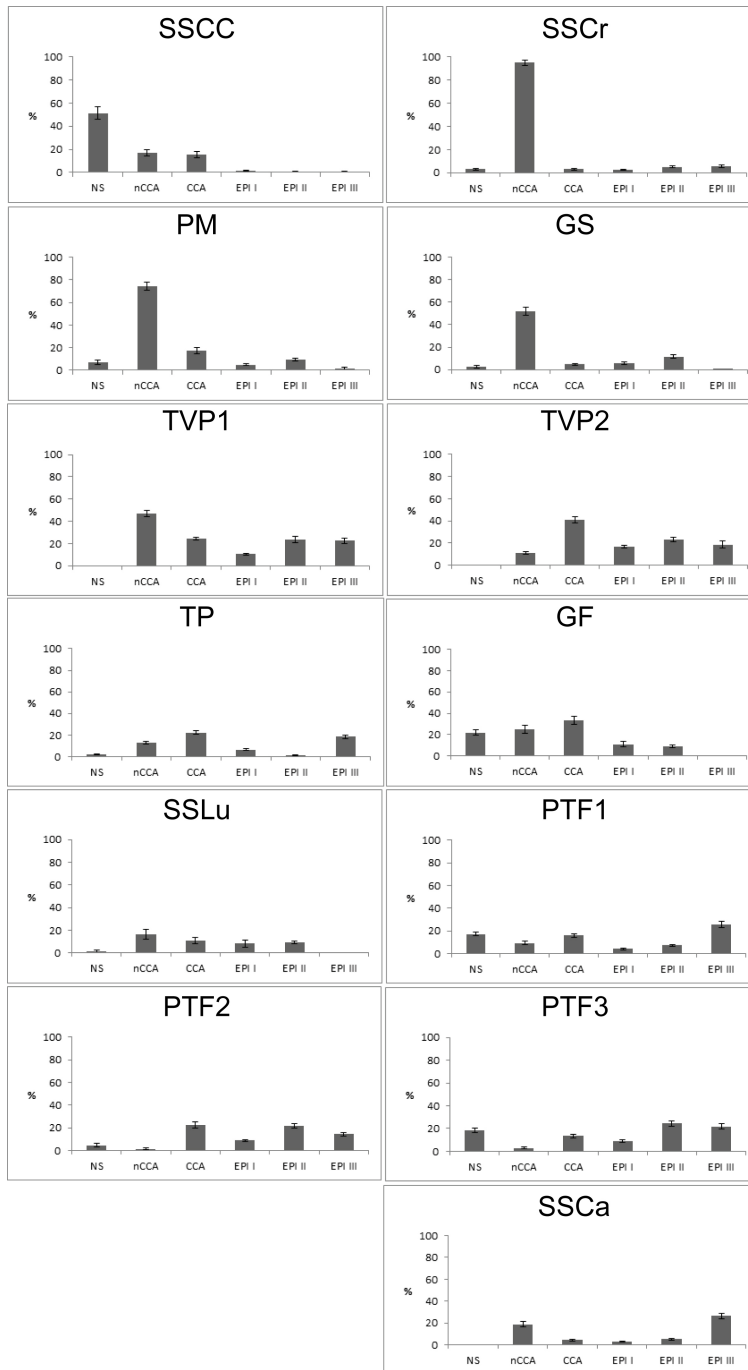
Figure 6: Frequencies percentages of Structural Descriptor in the stations in exam: nude substratum (NS), non-crustose coralline algae (nCCA), crustose coralline algae (CCA), encrusting/basal fauna (EPI I), massive fauna (EPI II) and branching fauna (EPI III).
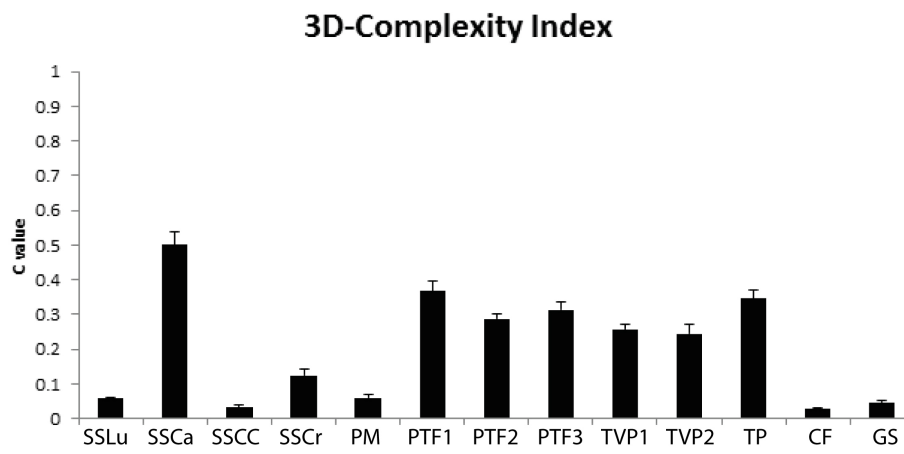
3D-Complexity Index

Figure 7: C Values of 3D- Complexity Index of the stations in exam.