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Integration of ESCA index through the use of sessile invertebrates

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Summary: The ESCA (Ecological Status of Coralligenous Assemblages) index was developed to assess the ecological quality of coralligenous habitat using macroalgae as a biological indicator. The aim of this study was to evaluate the response to human-induced pressures of macroalgae and sessile macro-invertebrates shaping the coralligenous habitat and to integrate their sensitivity into the ESCA index. Coralligenous assemblages were sampled at 15 locations of the NW Mediterranean Sea classified into three groups: i) marine protected areas; ii) low urbanized locations; and iii) highly urbanized locations. A sensitivity level value was assigned to each taxon/group on the basis of its abundance in each environmental condition, the data available in the literature and the results of an expert judgement survey. The index that includes the totality of the assemblages (named ESCA-TA), calculated using both macroalgae and sessile macro-invertebrates, detected the levels of human pressure more precisely than the index calculated with only macroalgae or with only invertebrates. The potential for assessing the ecological quality of marine coastal areas was thus increased with the ESCA-TA index thanks to the use of a higher variety of descriptors.

Keywords: coralligenous assemblages; ESCA and ESCA-TA indices; ecological quality; macroalgae; macro-invertebrates; Mediterranean Sea.

Integración de el índice ESCA por medio de los macro-invertebrados sésiles

Resumen: El índice ESCA (Estado Ecológico de las Comunidades Coralígenas) ha sido desarrollado para determinar el estado ecológico de los hábitats coralígenos utilizando macro-algas como indicador biológico. El objetivo de este estudio fue evaluar la respuesta, ante presiones antropogénicas, de macro-algas y macro-invertebrados sésiles moldeadores de la comunidad coralígena y su sensibilidad al índice ESCA. Se muestrearon comunidades coralígenas en 15 localizaciones del Mediterráneo Nord-Occidental clasificadas en 3 grupos: i) áreas marinas protegidas; ii) poco urbanizadas; iii) muy urbanizadas. Un valor de Nivel de Sensibilidad fue asignado a cada taxón/grupo en base a su abundancia en cada condición medioambiental, a información bibliográfica disponible y a los resultados de juicios por parte de expertos. El índice que integra la totalidad de las comunidades (llamado ESCA-TA), calculado usando tanto macro-algas como macro-invertebrados sésiles, detectó los diferentes niveles de presión humana de manera más precisa que el índice calculado solo con macro-algas o solo con invertebrados. El potencial para determinar el estado ecológico de las áreas marinas protegidas se incrementó con el índice ESCA-TA gracias al uso de una mayor variedad de descriptores.

Palabras clave: comunidades coralígenas; índices ESCA y ESCA-TA; estado ecológico; macro-algas; macro-invertebrados; mar Mediterráneo.

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INTRODUCTION

Coralligenous habitat is a biocostruction composed primarily by calcareous red algae belonging to Corallinales and Pessonneliales and secondarily by Cnidaria, Polychaeta and Bryozoa (Ballesteros 2006). It is one of the most important coastal ecosystems of the Mediterranean Sea for distribution, biodiversity, productivity and role in the CO_2 cycle (Bertolino et al. 2013, Martin et al. 2014, Casas-Guell et al. 2015). Coralligenous habitat is considered sensitive to human activities (Piazzi et al. 2012, Cánovas Molina et al. 2016) and has been included in the protection programme of European legislation (e.g. the Habitats Directive 92/43/EEC; the Marine Strategy Framework Directive 2008/56/EEC) as a habitat of high scientific interest and biodiversity ("special habitat type" sensu MSFD 2008/56/EEC) (EC 2008). The development of monitoring programmes to manage and conserve special marine habitats requires effective descriptors to evaluate their ecological status and to detect changes in their ecological quality (Birk et al. 2012). Several indices have been proposed for assessing the ecological quality of coralligenous assemblages: the Coralligenous Assemblage Index (CAI) (Deter et al. 2012), the Coralligenous Assessment by ReefScape Estimate (COARSE) (Gatti et al. 2015a), the INDEX-COR (Sartoretto et al. 2014) and the Ecological Status of Coralligenous Assemblages (ESCA) (Cecchi et al. 2014, Piazzi et al. 2015).

Several studies concerning responses of coralligenous assemblages to environmental stress have considered macroalgae as an effective biological indicator (Balata et al. 2007a, Piazzi et al. 2011, 2012) and results of these studies were used to develop the ESCA index. Conversely, little is known about the response of sessile coralligenous macro-invertebrates to stress, even if some taxa are recognized to be sensitive to human-induced alterations (Bavestrello et al. 1997, Garrabou et al. 1998, Gatti et al. 2015b). The concurrent use of both macroalgae and sessile macro-invertebrates allows a wider spectrum of human-induced alterations to be detected than when a single component is used, thus better evaluating the ecological quality of coralligenous assemblages (Kipson et al. 2011, Sartoretto et al. 2014, Gatti et al. 2012).

The aim of this study was to evaluate the response to environmental alterations of macroalgae and sessile macro-invertebrates shaping the coralligenous habitat and to integrate their sensitivity into the ESCA index. To achieve these objectives, coralligenous assemblages subjected to three different levels of human-induced pressure (protected, low urbanized and highly urbanized) were studied within a large geographic area of the western Mediterranean Sea. We adopted the scale of sensitivity of coralligenous species to human pressures developed by Montefalcone et al. (2017) on the basis of expert judgement. We compared the effectiveness of the three ESCA indices, calculated using only macroalgae, only macro-invertebrates, and the total assemblage.

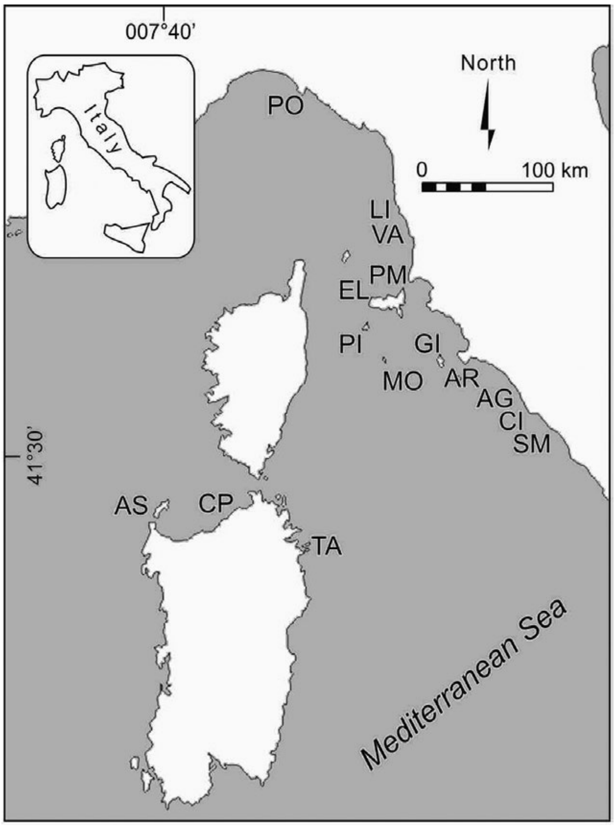

Fig. 1. – Map of the study locations: Portofino (PO), Livorno (LI), Vada Shoals (VA), Piombino (PM), Elba Island (EL), Pianosa Island (PI), Montecristo Island (MO), Giglio Island (GI), Argentario (AR), Sant'Agostino (AG), Civitavecchia (CI), Santa Marinella (SM), Asinara Island (AS), Costa Paradiso (CP), Tavolara Island (TA).

MATERIALS AND METHODS

Coralligenous assemblages were sampled at 15 locations of the NW Mediterranean Sea classified into three groups according to the level of human-induced pressure they are affected by. Five locations were in marine protected areas (MPAs) (Portofino, Montecristo Island, Pianosa Island, Tavolara Island and Asinara Island), five locations were unprotected but with a low level of urbanization (l-U) (Vada Shoals, Elba Island, Giglio Island, Argentario and Costa Paradiso) and five locations were subjected to a high level of urbanization (h-U) (Livorno, Piombino, Sant'Agostino, Civitavecchia and Santa Marinella) (Fig. 1). The level of urbanization for each location was determined according to the presence of local pressures (e.g. industries, ports and rivers) and the distance of the studied locations from these sources of pressure (Lopez y Royo et al. 2009, Piazzi et al. 2015). Although pristine ecosystems in the Mediterranean Sea can no longer be expected (Jackson and Sala 2001, Stachowitsch 2003) and the boundaries of MPAs do not protect them from the effects of global impacts such as climate change and water turbidity (Montefalcone et al. 2009, Parravicini et al. 2013, Mateos-Molina et al. 2015), the five locations selected within MPAs are characterized by low levels of urbanization and are protected from impacts related to human activities such as fishing and anchoring.

At each location, two sites of about 100 m^2 that were hundreds of metres apart were randomly selected on vertical rocky bottom between 30 and 40 m depth, and at each site three areas of 4 m^2 and tens of metres apart were selected. In each area, ten photographic samples of 0.2 m^2 were collected. Organisms easily detected by photographic samples were considered as taxa, while those displaying similar morphological features were assembled into morphological groups (Parravicini et al. 2010, Cecchi et al. 2014, Piazzi et al. 2014). The percentage cover of the main taxa/morphological groups was evaluated by a manual contouring technique through the ImageJ software (Cecchi et al. 2014).

The structure of assemblages was analysed by permutational analysis of variance (Primer6 + PERMANOVA, Anderson 2001) based on Bray-Curtis resemblance matrix of untransformed data. Data were not transformed in order to stress the importance of the abundance of taxa/groups in determining the differences among conditions (Clarke and Gorley 2006). A four-way model was used with Condition (3 levels: MPAs, l-U and h-U) as a fixed factor, Location (5 levels) as a random factor nested in Condition, Site (2 levels) as a random factor nested in Location, and Area (3 levels) as a random factor nested in Site. Pairwise tests were used to compare levels of significant factors. Homogeneity of multivariate dispersions was verified with PERMDISP (Anderson 2006) to test the robustness of PERMANOVA analysis with respect to sample dispersion (Anderson et al. 2008).

A canonical analysis of principal coordinates (CAP) conducted on a log(x+1) transformed Bray-Curtis resemblance matrix (Anderson and Robinson 2003, Anderson and Willis 2003) was performed in order to discriminate the differences of assemblages structure among conditions, highlighting species or taxa/groups as indicators accounting for this discrimination. A SIMPER analysis (Clarke 1993) was performed to identify percentage contribution of each species to the Bray-Curtis similarity among conditions.

A sensitivity level (SL) value was assigned to each taxon/group on the basis of its abundance in each environmental condition, data available in the literature (Hong 1983, Balata et al. 2005, Gatti et al. 2015b) and results from an expert judgement survey (Montefalcone et al. 2017), following an approach similar to that reported for the evaluation of shallow subtidal assemblages by the CARLIT index (Ballesteros et al. 2007). SL values varied according to a numerical scale ranging from 1 to 10, with minimum values corresponding to the most tolerant organisms and maximum values to the most sensitive ones (Cecchi et al. 2014). The cover values of the main taxa/morphological groups in each photographic sample were classified according to eight classes of abundance: 1) 0% to 0.01%; 2) 0.01% to 0.1%; 3) 0.1% to 1%; 4) 1% to 5%; 5) 5% to 25%; 6) 25% to 50%; 7) 50% to 75%; and 8) 75% to 100%. The total SL of each photographic sample (SL_{sa}) was calculated by multiplying the sensitivity value of each taxon/group by its class of abundance (from 1 to 8) and adding values of all taxa/groups present in the sample.

For the calculation of the ESCA (considering only macroalgae), the ESCA-A (considering only macroinvertebrates) and the ESCA-TA (considering the total assemblage, i.e. both macroalgae and macroinvertebrates) indices, the correspondent value of SL for a study site (SL_{si}) was obtained by averaging the SL_{sa} values of all samples (Cecchi et al. 2014). Alpha-diversity was defined as the mean number of the main taxa/groups obtained in each photographic sample. Beta-diversity was evaluated as the mean distance of all photographic samples from centroids calculated in the PERMDISP analysis (Primer 6 + PERMANOVA, Anderson et al. 2006). The indices were expressed as ecological quality ratio (EQR), calculated as the mean of the three EQR_i obtained for the assemblage descriptors $[(EQR_{SL}+EQR_{alpha}+EQR_{beta})/3]$. The EQR_i were calculated as ratios between values of each of the SL, alpha-diversity and beta-diversity obtained in the study site and values obtained for the same descriptors at a reference location (Montecristo Island; Cecchi et al. 2014). According to the values of the indices, the ecological quality was classified following boundaries proposed by Piazzi et al. (2015): high quality ($EQR\geq 0.8$); good quality ($0.6\leq EQR<0.8$); moderate quality ($0.4\leq EQR<0.6$); poor quality ($0.2\leq EQR<0.4$); and bad quality ($EQR<0.2$). One-way PERMANOVA analyses based on Euclidean distance of untransformed data (Anderson et al. 2008) were used to compare index values among conditions. Pair-wise tests were used to compare levels of significant factors.

A linear regression was performed in order to test the strength of the relationships between ESCA-TA and both ESCA and ESCA-A. The degree of correlation between EQR values was calculated and reported as the value of square correlation coefficient (determination coefficient, R^2). Significance of regression was tested by means of the Fisher-Snedecor test performed by the Statistica 10 software.

RESULTS

PERMANOVA analysis detected significant differences in the coralligenous assemblages among conditions, locations, sites and areas (Table 1). The pairwise test showed that differences were significant between h-U locations and the others but not between MPA and l-U locations (Table 1).

CAP analysis showed a clear and significant disjunction (permutation tests <0.05) along the CAP1 axis between groups of MPA/l-U locations and the h-U ones; secondly, discrimination between MPA and l-U locations along the CAP2 axis, can be detected, but on the basis of only a few taxa (Fig. 2). In fact, both MPA and l-U locations were generally characterized by a dominance of the Chlorophyta *Halimeda tuna* (J. Ellis et Solander) J.V. Lamouroux, *Flabellia petiolata* (Turra) Nizamuddin and *Palmophyllum crassum* (Naccari) Rabenhorst, erect Rhodophyta, erect bryozoans such as *Reteporella grimaldii* (Jullien, 1903), *Smittina cervicornis* (Pallas, 1766) and *Pentapora fascialis* (Pallas, 1766), and the Gorgoniidae *Eunicella cavolini* (Koch, 1887). Conversely, h-U locations were mostly

Table 1. – Results of PERMANOVA analysis on coralligenous assemblages. MPAs, marine protected areas; l-U, low urbanized locations; h-U, highly urbanized locations. Significant effects are in bold.

Source	df	MS	Pseudo-F	P(perm)
Condition = C	2	138000	2.76	**0.014**
Location (C) = L(C)	12	49992	3.02	**0.001**
Site (L(C)) = S(L(C))	15	16543	3.58	**0.001**
Area (S(L(C)))	60	4609	3.42	**0.001**
Residual	810	1345		

Pairwise test (C)	P(perm)
MPAs, l-U	0.252
MPAs, h-U	**0.018**
l-U, h-U	**0.048**

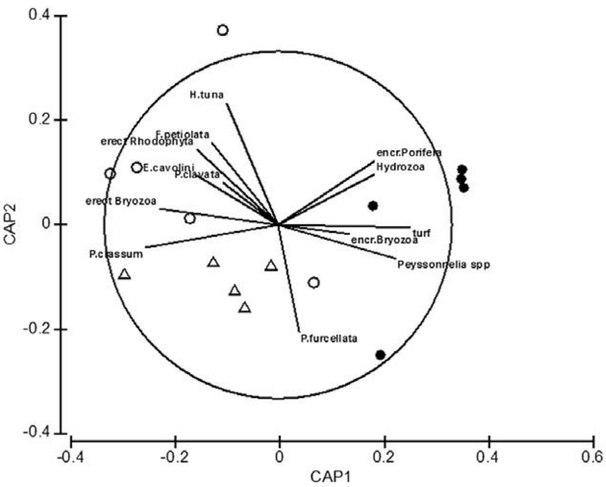

Fig. 2. – Canonical analysis of principal coordinates (CAP), showing the discriminant-type ordination of assemblages subjected to different levels of human pressure. MPAs, white circles; l-U, white triangles; h-U, black circles.

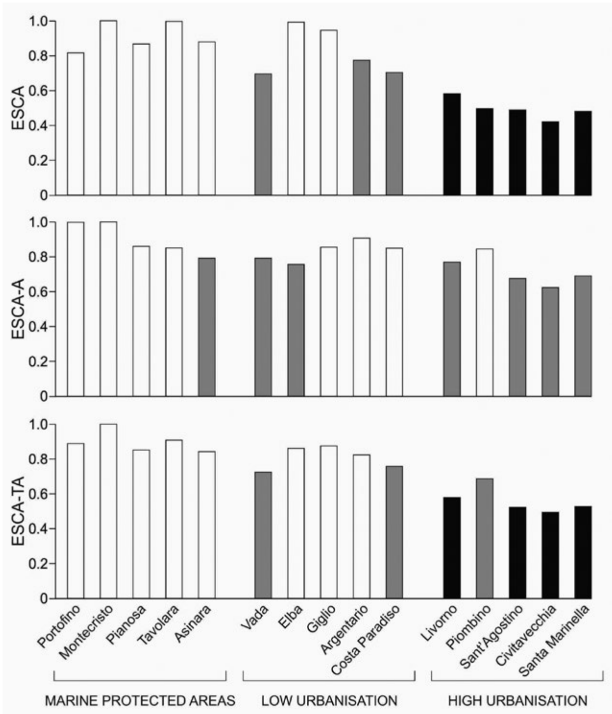

Fig. 3. – Values of the ESCA index calculated using only macroalgae and using only sessile macro-invertebrates (ESCA-A), and values of the integrated ESCA-TA index calculated using both macroalgae and sessile macro-invertebrates (i.e. the total assemblage) at the locations grouped according to their condition (MPAs, low urbanized and highly urbanized). White, high ecological quality; grey, good ecological quality; black, moderate ecological quality.

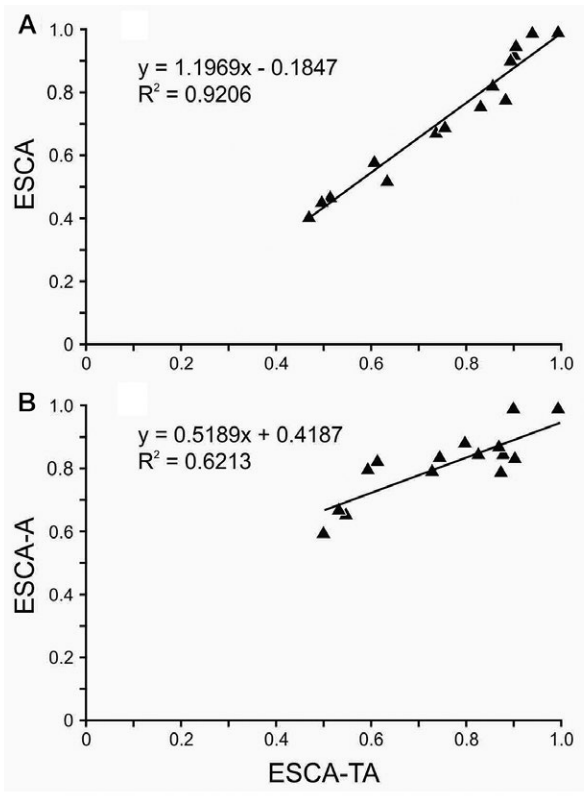

Fig. 4. – Relationships between the ESCA-TA index and the ESCA (A) and the ESCA-A (B) indices. The equations and the values of the determination coefficients (R^2) are reported, n=15.

Table 2. – Results of SIMPER test. MPAs, marine protected areas; l-U, low urbanized locations; h-U, highly urbanized locations.

Taxa/Groups	Av. Abundance MPAs	h-U	Av. dissimilarity
Erect Rhodophyta	10.2	0.3	14.39
Turf	9.7	32.9	14.06
Halimeda tuna	4.4	0	9.89
Peyssonnelia spp.	11.4	24.3	8.68
Flabellia petiolata	3.1	0.8	7.68
Encrusting Porifera	2.2	3.2	4.68
Erect Bryozoa	0.9	0.1	4.64
Dictyotales	0.6	0.1	4.09
Pseudochlorodesmis furcellata	0.3	0.6	3.77
Palmophyllum crassum	0.4	0	3.35
Eunicella cavolini	0.8	0.4	2.44
Paramuricea clavata	1.3	0.1	1.55
	l-U	h-U	
Turf	15.7	32.9	15.51
Peyssonnelia spp.	7.8	24.3	14.14
Erect Rhodophyta	2.6	0.3	10.4
Alcyonacea	1.4	0.8	7.2
Flabellia petiolata	1.4	0.8	6.24
Encrusting Porifera	1.8	3.2	5.79
Pseudochlorodesmis furcellata	0.5	0.6	5.45
Halimeda tuna	0.6	0	5.36
Palmophyllum crassum	0.3	0	3.83
Encrusting Bryozoa	0.2	0.4	2.96
Eunicella cavolini	0.6	0.4	1.44

Table 3. – Sensitivity Level (SL) of the main taxa/morphological groups in the coralligenous assemblages.

Taxa/Groups	SL
Algal turf	1
Hydrozoans (e.g. *Eudendrium* spp.)	2
Pseudochlorodesmis furcellata	2
Perforating sponges (e.g. *Cliona* spp.)	2
Dyctiotales	3
Encrusting sponges	3
Encrusting bryozoans	3
Encrusting ascidians (also epibiontic)	3
Encrusting Corallinales, articulated Corallinales	4
Peyssonnelia spp.	4
Valonia spp., *Codium* spp.	4
Sponges prostrate (e.g. *Chondrosia reniformis, Petrosia ficiformis*)	5
Large serpulids (e.g. *Protula tubularia, Serpula vermicularis*)	5
Parazoanthus axinellae	5
Leptogorgia sarmentosa	5
Flabellia petiolata	6
Erect corticated terete Ochrophyta (e.g. *Sporochnus pedunculatus*)	6
Encrusting Ochrophyta (e.g. *Zanardinia typus*)	6
Azooxantellate individual scleractinians (e.g. *Leptopsammia pruvoti*)	6
Ramified bryozoans (e.g. *Caberea boryi, Cellaria fistulosa*)	6
Palmophyllum crassum	7
Arborescent and massive sponges (e.g. *Axinella polypoides*)	7
Salmacina-Filograna complex	7
Myriapora truncata	7
Erect corticated terete Rodophyta (e.g. *Osmundea pelagosae*)	8
Bushy sponges (e.g. *Axinella damicornis, Acanthella acuta*)	8
Eunicella verrucosa, Alcyonium acaule	8
Erect ascidians	8
Corallium rubrum, Paramuricea clavata, Alcyonium coralloides	9
Zooxantellate scleractinians (e.g. *Cladocora caespitosa*)	9
Pentapora fascialis	9
Flattened Rhodophyta with cortication (e.g. *Kallymenia* spp.)	10
Halimeda tuna	10
Fucales (e.g. *Cystoseira* spp., *Sargassum* spp.), *Phyllariopsis brevipes, Laminaria rodriguezii*	10
Eunicella singularis, Eunicella cavolini, Savalia savaglia	10
Aedonella calveti, Reteporella grimaldii, Smittina cervicornis	10

Table 4. – Results of PERMANOVA analyses on the three indices (ESCA-TA, ESCA, ESCA-A). MPAs, marine protected areas; l-U, low urbanized locations; h-U, highly urbanized locations. Significant effects are in bold.

		ESCA-TA			ESCA			ESCA-A		
Source	df	MS	Pseudo-F	P(perm)	MS	Pseudo-F	P(perm)	MS	Pseudo-F	P(perm)
Condition	2	795	53.74	**0.001**	1253	30.47	**0.001**	165	7.02	**0.014**
Residual	12	14			41			23		
Pairwise test			P(perm)			P(perm)			P(perm)	
MPAs, l-U			**0.023**			0.168			0.266	
MPAs, h-U			**0.010**			**0.008**			**0.016**	
l-U, h-U			**0.015**			**0.008**			**0.033**	

characterized by turf macroalgae, *Peyssonnelia* spp, Hydrozoa, encrusting Bryozoa, encrusting Porifera and the Chlorophyta *Pseudochlorodesmis furcellata* (Zanardini) Børgesen. The SIMPER test confirmed the dominance of the main taxa/groups responsible for the CAP grouping (Table 2).

The SL assigned to each taxon/group is shown in Table 3. Values of the three ESCA indices ranged between high and moderate quality (Fig. 3). PERMANOVA highlighted significant differences among conditions for ESCA, ESCA-A and ESCA-TA. However, the pair-wise test showed that differences between MPA and l-U conditions were significant only when the ESCA-TA was used, while the same means comparison was not significant for the other two indices (ESCA and ESCA-A) (Table 4). Significant differences among other conditions (MPAs vs h-U and l-U vs h-U) were detected for all three indices (Table 4).

Significant positive correlations between the ESCA-TA index and both the ESCA and the ESCA-A indices were highlighted, with a higher correlation ($P<0.0001$, Fig. 4A) with ESCA than with ESCA-A ($P<0.001$, Fig. 4B). Values of the determination coefficient and line slope confirmed a strong association between the two variables in the case of ESCA-TA and ESCA ($b=1.2$; $R^2=0.9206$), while the linear relation between ESCA-TA and ESCA-A was weaker ($b=0.52$; $R^2=0.613$).

DISCUSSION

Results showed differences in the structure of coralligenous assemblages between locations characterized by different levels of human-induced pressure, and these differences were related to different abundances of both macroalgae and sessile macro-invertebrates. These patterns confirm the sensitivity of coralligenous assemblages to human pressure (Balata et al. 2007b, Piazzi et al. 2012, Gatti et al. 2015b), highlighting the suitability of these assemblages to be used as ecological indicators in monitoring survey and impact evaluation studies (Deter et al. 2012, Sartoretto et al. 2014, Gatti et al. 2015a). Also, local protection might be not enough to prevent impacts on the structure and the ecological quality of coralligenous assemblages, as many organisms are more sensitive to large-scale alterations of water quality than to local disturbances (Parravicini et al. 2013).

Changes in macroalga abundance and composition among the studied environmental conditions were in agreement with patterns widely described (Piazzi et al. 2012 and references therein). The main differences between conditions were related to the abundance of algal turfs, which increased at the high urbanized locations where, instead, the erect Rhodophyta and Udoteaceae (*Halimeda tuna* and *Flabellia petiolata*) decreased significantly. Turfs are mostly constituted by filamentous species that reproduce asexually and are well adapted to environmental stress (Balata et al. 2011). In fact, filamentous forms are favoured by eutrophication, thanks to their high uptake efficiency, and are adapted to high sedimentation rates because they are able to quickly recover after disturbance (Taylor et al. 1998, Airoldi 2003). Conversely, erect macroalgae reproducing by spores suffer conditions induced by high urbanization as they are damaged directly by eutrophication and high sedimentation rates, and indirectly because they are out-competed by turfs that become dominant under stress conditions (Balata et al. 2011).

This study also highlighted changes in the abundance of several taxa/groups of sessile macro-invertebrates among conditions, confirming patterns suggested by previous investigations (Hong 1983, Ponti et al. 2011, Piazzi et al. 2016). In particular, erect bryozoans and some gorgonians showed lower abundance at highly urbanized sites, while hydrozoans, sponges and encrusting bryozoans seemed to be the most tolerant taxa. The sensitivity of erect bryozoans to different kinds of pressure linked with water quality alteration or mechanical disturbance has already been reported (Sala et al. 1996, Garrabou et al. 1998, de la Nuez-Hernández et al. 2014), although the level of tolerance varies among species (Harmelin and Capo 2001). Thus, these organisms may be considered as valuable indicators of isolated or chronic impacts (Deter et al. 2012, Gatti et al. 2015a). Gorgonians, because of their long life and slow dynamics, are particularly vulnerable to large-scale alterations such as climatic anomalies (Linares et al. 2008, Garrabou et al. 2009, Teixidó et al. 2013), which are independent of the level of local protection (Cerrano et al. 2000, Coma et al. 2006, Huete-Stauffer et al. 2011). However, local disturbances (such as sedimentation, anchoring and fishing activities) can also affect gorgonian populations, causing damage of varying extent (Bavestrello et al. 1997) and explaining the patterns highlighted in the study.

The increase in the distribution of encrusting sponges at highly urbanized locations confirms patterns already described (Hong 1983, Ponti et al. 2011); in fact, high abundances of these organisms have been reported for degraded areas characterized by high levels of fine sediments and organic matter (Falace et al. 2015). By contrast, erect sponges did not appear as tolerant opportunistic species (Teixidó et al. 2011, Gatti et al. 2015b).

Algae and animals are known to respond differently to environmental stressors due to their different life histories and life cycles (Grime 1977, Darling et al. 2012 and references therein). Thus, depending on which of the two components is dominant in a coralligenous assemblages, the two individual indices considering only animals (ESCA-A) or only algae (ESCA) can be used accordingly and then also compared to understand which of the two components has been mostly affected. On the other hand, the concurrent use of the two components in the integrated ESCA-TA index can be effective in all the most common situations of high biodiverse coralligenous assemblages, as well as in situations where periodical fluctuations between animal-dominated and algal-dominated assemblages occur due to synergistic effects of local and global impacts (Parravicini et al. 2013, Gatti et al. 2015b). The results of this paper also showed that, although both the ESCA and ESCA-A indices, when used alone, clearly separated the highly urbanized locations from the other ones, the ESCA-TA index detected more finely the three environmental conditions, also revealing those subtle differences between locations under a regime of protection and locations affected by low levels of urbanization. The higher degree of correlation between ESCA-TA and ESCA suggests a higher sensitivity of macroalgae, compared with macro-invertebrates, to those environmental alterations that usually occur in the urbanized areas, such as the increase in nutrients and water turbidity (Lopez y Royo et al. 2009). By contrast, sessile animals can be more sensitive than macroalgae to other kinds of stress, such as effects of climate changes and mechanical disturbances due to fishing, recreational diving and anchoring (Cerrano et al. 2000, Coma et al. 2006, de la Nuez-Hernández et al. 2014). Thus, combining macroalgae and macro-invertebrates into the ESCA-TA index may increase the efficiency of the index in determining the ecological quality of marine coastal areas, as the response spectrum of the index to human pressures can be extended by the use of a higher number of descriptors. Moreover, the use of the ESCA-TA index may allow a finer intercalibration with other monitoring methods that consider the whole coralligenous assemblages (Kipson et al. 2011, Deter et al. 2012, Gatti et al. 2015a), and therefore meet the requirements of the European directives.

Due to the high biodiversity that characterizes coralligenous assemblages (Ballesteros 2006), the list we proposed is based on the most characteristic taxa and on a number of morphological groups that, according to the main literature and to our data, can be easily recognized and classified in photographic samples. The SLs of each taxon/group used for the calculation of the ESCA indices are then based on results of the present and previous studies related to the northwestern Mediterranean Sea, as well as on results of an expert judgement survey (Montefalcone et al. 2017). The scores of sensitivity we assumed can be shared within a broad group of species but, sometimes, sensitivity cannot be synthesized into an univocal score that is suitable for all members of a group (Montefalcone et al. 2017): this is why our list of taxa/groups, with their relative scores of sensitivity, should be tested in other geographical situations in order to be consistently adapted, case by case, and then improved. Further studies would therefore be desirable. Should the method be considered effective, the SLs, as well as the reference site for computing the EQR, could be modified following an approach already used for other ecological quality indices (Bermejio et al. 2013, Nikolic et al. 2013) and testing the sensitivity of coralligenous organisms to different kinds of stress and within a larger geographic area.

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