

**The two facets of species sensitivity: stress and disturbance on coralligenous assemblages in
space and time**

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Abstract

Marine coastal ecosystems are affected by a vast array of human-induced disturbances and stresses, often capable of overwhelming the effects of natural changes. Notwithstanding the conceptual and practical difficulty to differentiate between disturbance and stress, which are often used interchangeably, the two terms bear a different ecological meaning. Both are external agents but the former causes mortality or physical damage (subtraction of biomass), the latter physiological alteration (reduction of productivity). Sensitivity of marine organisms may thus have a dual connotation, being influenced in a different way by disturbance or by stress following major environmental change. Coralligenous assemblages, shaping unique biogenic formations in the Mediterranean Sea, are considered highly sensitive to change. In this paper we propose a method to differentiate disturbance and stress in order to assess the ecological status of coralligenous assemblages. Disturbance Sensitivity Level (DSL) and Stress Sensitivity Level (SSL) of the sessile organisms thriving in the coralligenous were combined into the Integrated Sensitivity Level of coralligenous Assemblages (ISLA) index. Changes in coralligenous status were assessed in space, along a gradient of stress (human-induced pressures) in several sites of the Western Mediterranean, and in time, from a long-term series (1961 to 2008) of Mesco Reef (Ligurian Sea) encompassing a mass mortality event in the 1990s. The quality of coralligenous assemblages was lower in highly urbanised sites with respect to sites in both marine protected areas and with low levels of urbanisation, and decreased at Mesco Reef during the last 50 years. Reduction of quality was mainly due to the increase of stress-tolerant and/or opportunist species (e.g. algal turfs, hydroids and encrusting sponges), to the disappearance of the most sensitive macroalgae (e.g. Udoteaceae and erect Rhodophyta) and macro-invertebrates (e.g. *Savalia savaglia*, *Alcyonium coralloides*, *Smittina cervicornis*) and to the appearance of invasive alien algal species. While the specific indices of sensitivity to stress (SSL) or disturbance (DSL) illustrated better the changes in the spatial or temporal datasets, respectively, their integration in ISLA showed effective in measuring change experienced by coralligenous assemblages in either space and time.

Keywords: stress; disturbance; sensitivity; ISLA index; ecological quality; coralligenous assemblages; Mediterranean Sea.

1. Introduction

Most ecosystems are, directly or indirectly, under the human control (Crutzen, 2002). Heavy and unprecedented human-induced impacts are today widespread, which often are capable of overwhelming the effects of natural change. Marine coastal ecosystems, in particular, are declining around the world across a broad range of spatial and temporal scales. In many regions, they have already been significantly altered by overfishing, pollution, eutrophication, global warming, ocean acidification, and spread of invasive species (Thrush et al., 2009). Ecosystems are therefore affected by a large array of disturbances and stresses undermining, either abruptly or gradually, their state of health.

A sharp and rigid distinction, both conceptual and practical, between disturbance and stress has been hardly achieved, and much depends on the intensity and duration of external affectors involved. The terms disturbance and stress are also often used interchangeably: they have, in fact, the general meaning of worry (Montefalcone et al., 2011). However, stress and disturbance have a different ecological connotation and the most useful and clear definitions are those given by Grime (1977). He stated that both disturbance and stress are external factors (i.e. causes): subtraction (partial or total) of biomass is the primary effect of disturbance, whilst reduced production is the primary effect of stress. Effects of disturbance may be evidenced by a discrete, punctuated mortality, displacement, or damaging of one or more individuals (or colonies) that directly or indirectly creates an opportunity for new individuals (or colonies) to become established (Sousa, 1984). A stress may induce a condition of physiological alteration in organisms or populations in response to variations in the levels of environmental factors and occurs below the intensity that produces mortality and/or the time that allows adaptation (Levitt, 1972).

According to their biological characteristics (e.g. longevity, size, susceptibility to contaminants, etc.), organisms may display different levels of sensitivity to disturbance (that is the contrary of resistance) and different levels of sensitivity to stress (that is the contrary of tolerance) (García-Gómez, 2015). The sensitivity to disturbance refers to susceptibility of organisms to be physically injured or killed by exposure to specified external factors (e.g. mechanical impacts, climate anomalies) and to the ability of survivors to adjust to change and then recover. The sensitivity to stress refers to the capacity of an organism to tolerate and to cope with, eventually adapting to, altered environmental quality (e.g. pollution, water turbidity). Extremely stressed environments favour, according to Grime (1977), communities composed by stress-tolerant species that withstand those conditions. Stress-tolerant species have low production ability because they have to spend energy to cope with the stress. It can be argued that stress implies the possibility of adaptation and the metabolic cost of adaptation implies a limitation of production. External factors such as substratum loss, overfishing, anchoring, climate anomalies, and spread of invasive species can conversely be viewed as disturbances. Coupling sensitivity to disturbance (or resistance) and sensitivity to stress (or tolerance), each species is characterized by its own resilience to environmental alterations. In ecology, resilience is a complex cluster of concepts to describe the stability of ecosystems and their responses to external perturbations, focussing in particular on their ability to recover (i.e. to return to its previous condition) after a perturbation (Holling, 1973; Montefalcone et al., 2011).

Species sensitivity is a commonly used descriptor in various ecological indices for assessing marine environmental quality as requested by the most recent European Directives, i.e. the Water Framework Directive (WFD) (EC, 2000) and the Marine Strategy Framework Directive (MSFD) (EC, 2008) (García-Gómez, 2015; Leonardsson et al., 2015). A high sensitivity value means that the species is seldom found in altered environments. A low sensitivity value, on the other hand, means that the species can be found predominantly in altered environments (Harmelin and Capo, 2002). Among the marine habitats proposed to be adopted to monitor the health status of coastal waters,

the coralligenous is one of the most important in the Mediterranean Sea because of its high biodiversity and the role it plays in the carbonate cycle (Laborel, 1961, 1987; UNEP, 2007). Being the main calcareous formation of biogenic origin in the Mediterranean, coralligenous was included among the “special habitat types” that should be assessed under the MSFD (EC, 2008) through accurate monitoring plans. Coralligenous is the typical rocky habitat of the circalittoral Mediterranean zone and is characterized by bio-construction primarily due to calcareous red algae belonging to Corallinales and Peyssonneliales and secondarily by cnidarians, polychaetes and bryozoans (Ballesteros, 2006; Martin et al., 2014). The maintenance of this habitat is due to a delicate balance between bio-construction and bio-erosion, which can be easily broken by natural extreme events or human-induced perturbations (Ballesteros, 2006, and reference therein). Thus, coralligenous assemblages are considered highly sensitive to stress following water quality alteration, such as sedimentation, pollution and eutrophication, as well as extremely sensitive to disturbances such as for instance invasion by alien species, mechanical destruction by fishing or anchoring, and global warming (Hong, 1983; Piazzini et al., 2012; Gatti et al., 2015a, 2015b). All these pressures act synergically on coralligenous assemblages modifying the patterns of spatial variability and causing shifts in the structure and composition of assemblages through the decrease of sensitive organisms and the increase of resistant and tolerant ones (Gray, 1997; Arevalo et al., 2007; Piazzini and Balata, 2011).

Previous indices that adopted sensitivity of coralligenous species as a descriptor of ecological quality considered only the sensitivity to stress induced by water quality alteration, and used macroalgae to evaluate responses of assemblages to human-induced stress (Balata et al., 2007a, 2007b, 2011; Piazzini et al., 2011, 2012, 2015; Cecchi et al., 2014). Although sessile macro-invertebrates are a dominant component of coralligenous assemblages (Ballesteros, 2006) and are considered also sensitive to different pressures (Garrabou et al., 1998, 2009; Cerrano et al., 2000; Balata et al., 2005, 2007a; Kipson et al., 2011; Deter et al., 2012; Gatti et al., 2012, 2015a, 2015b), their different responses to stress and disturbance have rarely been addressed. Macro-invertebrates

have been widely used to evaluate the ecological quality of soft-bottom habitats (Borja et al., 2000; Simboura and Zenetos, 2002; Rosenberg et al., 2004; Teixeira et al., 2009) and only one method has been proposed for macro-invertebrates of shallow rocky bottoms (Orlando-Bonaca et al., 2012).

The aim of this paper is to propose a method to distinct and measure the sensitivity to stress and the sensitivity to disturbance of the sessile organisms thriving in coralligenous assemblages. An integrated ecological index, based on a biocoenotic approach and combining the two components of sensitivity, was then elaborated to assess the ecological status of the coralligenous habitat. The following steps have been performed:

- i) a list of the main taxa or morphological groups of macroalgae and sessile macro-invertebrates of coralligenous assemblages was compiled;
- ii) the sensitivity level of taxa/morphological groups to disturbance using their biological traits was evaluated;
- iii) the sensitivity level of taxa/morphological groups to stress was evaluated using an expert judgment approach;
- iv) sensitivity to disturbance and sensitivity to stress were combined into an integrated value of sensitivity level for each taxon/morphological group to anthropogenic pressures, and the Integrated Sensitivity Level of coralligenous Assemblages (ISLA) index was thus defined to evaluate the ecological status of the coralligenous;
- v) the effectiveness of the ISLA index in space and time was tested on two different datasets: 1) a “spatial” dataset obtained from different sites of the Western Mediterranean Sea along a gradient of human-induced pressure; 2) a “temporal” dataset obtained from long-term assessment (1961 to 2008), encompassing a mass mortality event in the 1990s, of the coralligenous of Mesco Reef (Ligurian Sea, NW Mediterranean).

2. Methods

2.1 Coralligenous assemblages

We compiled a list of the most characteristic macroalgae and sessile macro-invertebrates that can be found in coralligenous assemblages (Table 1), following Ballesteros (2006), Cecchi et al. (2014), Gatti et al. (2015b) and Piazzini et al. (2015). We also considered a number of Operational Taxonomic Units (OTUs) that can be easily recognised on photographs, which lump taxa into morphological groups where all species display similar morphological features (see for instance Balata et al., 2011; Cecchi et al., 2014).

2.2 Sensitivity level to disturbance (DSL)

To evaluate the sensitivity level to disturbance (DSL) of each taxon/morphological group, we inspired to the method proposed by Darling et al. (2012), who predicted how different benthic species respond to environmental disturbances inferring their life-history strategies from biological traits. A trait-based classification approach was thus applied, and a total of 6 commonly available biological traits were used to classify the DSL of coralligenous taxa/groups: 1) individual/colony growth form; 2) reproductive mode; 3) individual/colony size; 4) growth rate; 5) bioconstruction potential; 6) generation time (Table 2). We specifically focused on traits that were expected to affect sensitivity of species, and for which quantitative data were available in the literature. To each trait a score, ranging from 1 to 3, was assigned as described in Table 1. Summing all scores obtained from the 6 biological traits we computed the final score of DSL for each taxon/group, which may range from a minimum value of 6 to a maximum value of 18 (Table 2). The final value of DSL was assigned according to three classes of sensitivity to disturbance: low sensitivity (i.e. resistant), 6 to 9; medium, 10 to 14; and high sensitivity, 15 to 18 (see Table 2).

2.3 Sensitivity level to stress (SSL)

Marine benthic fauna encompasses thousands of species and most of them occur at low densities so that knowledge about the ecology of many species is limited, which makes it hard to generalize and to assign a single sensitivity level to stress for many species. Species sensitivity classifications used

so far are based on literature data combined with expert knowledge (e.g. Borja et al., 2000; Ballesteros et al., 2007; Teixeira et al., 2009; Cecchi et al., 2014; García-Gómez, 2015). To define the sensitivity level to stress (SSL) of coralligenous taxa/morphological groups we based on previous knowledge gathered from the available literature on this subject and we also designed an expert survey to evaluate the sensitivity of each taxon/group to the main environmental stress related to water quality alteration. The list of the main taxa/groups of macroalgae and sessile macro-invertebrates of the coralligenous assemblages (Table 1) was provided to scientific experts, whom were asked to score each taxon/group with a value ranging from 0 (not sensitive at all, i.e. tolerant) to 12 (highly sensitive), according to their sensitivity to the main present-day stressors that may alter water quality (e.g. eutrophication, pollution, hydrological changes, acidification, and turbidity). We proposed to experts 13 levels of SSL to obtain the same number of levels than the DSL (which ranges from 6 to 18).

2.4 Integrated sensitivity level (ISL)

Sensitivity level to disturbance (DSL) and sensitivity level to stress (SSL) of each taxon/group were combined into an integrated value, inspired to Ballesteros et al. (2007), representing the integrated sensitivity level (ISL) of coralligenous species to anthropogenic pressures (Fig. 1). DSL and SSL values were standardised using the following formula: $(x_i - x_{\min}) \times (x_{\max} - x_{\min})^{-1}$, where x_i is the SSL or the DSL of the taxon/group, $x_{\min} = 0$ or 6 (for SSL or DSL, respectively) and $x_{\max} = 12$ or 18 (for SSL or DSL, respectively). In this way, both DSL and SSL varied between 0 and 1. The ISL value was computed for each taxon/group with the following formula: $ISL = \sqrt{(DSL^2 + SSL^2)}$. Resulting values of ISL (ranging from 0 to $\sqrt{2}$) were then homogeneously scored along a numerical scale from 0 to 9 (see score assignment in Fig. 1), with minimum values corresponding to the most tolerant and resistant organisms (i.e. not sensitive at all) and maximum values corresponding to the most sensitive (Table 1). We assigned a negative value to the corresponding score of ISL of the

invasive alien species because they have always been defined as an impact by the European Directives (EC, 2000, 2008), thus subtracting ecological quality to native ecosystems.

2.5 Temporal dataset

Long-term assessment of the coralligenous of Mesco Reef (MR) (Ligurian Sea, NW Mediterranean) (Fig. 2) was performed in order to measure community changes over time from 1961 to 2008 (Gatti et al., 2015b). In this site, photographic samplings were carried out in four distinct periods: 1961, 1990, 1996 and 2008. During each period, five stations (C, D, F, I, S) tens of meters apart were randomly selected between 25 and 45 m depth, but in 1990 when only stations I and S were sampled. In each station three replicated and randomly distributed photographic samplings were performed on the vertical rocky bottom to cover a total area of 3 m² per photographic sample (3 photos of 1 m² each per sample).

2.6 Spatial dataset

Coralligenous assemblages were sampled in 15 sites of the North-Western Mediterranean Sea selected along a gradient of human-induced pressures (Fig. 2). Five sites were located in marine protected areas and named “protected” (P): Portofino (PO), Montecristo Island (MO), Pianosa Island (PI), Tavolara Island (TA), Capo Carbonara (CC). Five sites were chosen, according to the method of Lopez y Rojo et al. (2009), in unprotected areas with a low level of urbanisation, and named “low urbanised” (LU): Vada Shoals (VA), Elba Island (EL), Argentario (AR), Giglio Island (GI) and Costa Paradiso (CP). Finally, five sites were selected in highly urbanised areas and called as “high urbanised” (HU): Meloria Shoals (ME), Livorno (LI), Piombino (PB), Civitavecchia (CI), Santa Marinella (SM).

At each site, two areas 100s of meters apart were randomly selected and in each area three replicated photographic samplings were performed on vertical rocky bottoms between 30 and 35 m depth to collect 10 photos of 0.2 m² each per sample, totalling an area of 2 m² (30 photos per site).

2.7 Ecological indices

All photo-samples from both datasets were analysed to obtain the percent cover of conspicuous taxa/morphological groups characterizing the coralligenous assemblages (Parravicini et al., 2010, 2013; Balata et al., 2011; Piazzì et al., 2015). Two data matrices, (photo-samples \times sites) \times taxa/groups and (photo-samples \times times) \times taxa/groups, were organised on the basis of cover data for the spatial and the temporal datasets, respectively. Cover values of each taxon/group in the two matrices were then classified in 8 classes of abundances inspired to Boudouresque (1971): 1) $\% < 0.01$; 2) $0.01 \leq \% < 0.1$; 3) $0.1 \leq \% < 1$; 4) $1 \leq \% < 5$; 5) $5 \leq \% < 25$; 6) $25 \leq \% < 50$; 7) $50 \leq \% < 75$; 8) $75 \leq \% < 100$.

Abundance (as classes) for each taxon/group was multiplied by the corresponding score of SSL, DSL and ISL (Table 1) and the final values were summed up for the whole assemblage to have the total score of each photo-samples \times sites and photo-samples \times times. Three ecological indices were then obtained: i) the stress sensitivity level index (SSL index), ii) the disturbance sensitivity level index (DSL index), and iii) the Integrated Sensitivity Level of coralligenous Assemblages index (ISLA index), the latter integrating the two components of sensitivity into a single value. For each index we finally averaged the values from the three replicated photographic samples in each dataset. To define the ecological quality of coralligenous assemblages, the three indices were then expressed as Ecological Quality Ratio (EQR), calculated as the ratio between the values of the SSL, DSL and ISLA indices in each photographic sampling and the value of the respective index obtained in the reference condition, which has been defined as the highest index value obtained in the site of Montecristo (Cecchi et al., 2014) in the spatial dataset, and as the highest index value obtained in the year 1961 in the temporal dataset.

In the spatial dataset, the values of the SSL and DSL indices were correlated with the level of human pressure using the Pearson correlation coefficient. According to the values of the ISLA index, and inspiring to Piazzì et al. (2015), the ecological quality measured with the integration of

both the components of sensitivity was classified as follows: high quality ($ISLA \geq 0.8$); good quality ($0.6 \leq ISLA < 0.8$); moderate quality ($0.4 \leq ISLA < 0.6$); poor quality ($0.2 \leq ISLA < 0.4$); bad quality ($ISLA < 0.2$).

2.8 Data analysis

The structure of assemblages in both datasets was analysed by permutational analysis of variance (PERMANOVA) (Anderson, 2001). A three-way model was used in the spatial dataset with condition (3 levels: protected, low urbanised and high urbanised) as fixed factor, site (5 levels per condition) as random factor nested in condition, area (2 levels) as random factor nested in site, with three replicated photographic samples per area. A two-way model was used in the temporal dataset with year (4 levels: 1961, 1990, 1996, 2008) as fixed factor and station (5 levels per year, except in 1990 with 2 levels) as random factor nested in time, with three replicated photographic samples per station. Pair-wise tests were used to compare levels of significant factors. A SIMPER analysis (Clarke, 1993) was performed to identify percentage contribution of each taxon/group to the Bray-Curtis dissimilarity among conditions and years.

One-way PERMANOVA analyses were used to test for differences in the ISLA index among years (1961, 1990, 1996, 2008) in the temporal dataset and among conditions (protected, low urbanised and high urbanised) in the spatial dataset. Homogeneity of multivariate dispersions was verified with PERMDISP (Anderson, 2006) to test the robustness of PERMANOVA respect to sample dispersion (Anderson et al., 2008). Pair-wise tests were used to compare levels of significant factors.

3. Results

3.1 Sensitivity

A total of 31 taxa and 23 OTUs were defined as representative of coralligenous assemblages; their level of sensitivity to disturbance (DSL), their level of sensitivity to stress (SSL) and their final

integrated value of sensitivity (ISL) were computed (Table 1 and Fig. 1). 24% of these taxa/groups are both resistant and tolerant (not sensitive at all), 35% display high sensitivity to stress and to disturbance, whilst 22% are resistant to disturbance but highly sensitive to stress and 19% are tolerant to stress but highly sensitive to disturbance (Fig. 1).

3.2 Temporal dataset

Quality of the coralligenous at Mesco Reef showed a different temporal trend using the DSL index or the SSL index. Considering only the effects of disturbance, a great reduction of quality was evident between 1990 and 1996 (Fig. 3a), followed by a complete recovery in the last period (i.e. 2008); on the contrary, considering only the effects of stress, quality of the coralligenous showed a steady and continuous reduction from 1961 to 1996, which then maintained at constant values until 2008 (Fig. 3b). Coupling stress and disturbance within the integrated ISLA index, the quality of Mesco Reef decreased from 1961 (0.77 ± 0.05) to 1990 (0.70 ± 0.1) (Fig. 4a), although differences were not significant (Table 3); in both periods coralligenous showed a good quality, notwithstanding the larger variability in the latter period. In the following 6 years, from 1990 to 1996 the quality of coralligenous dropped down to a value of 0.51 ± 0.03 , shifting to a moderate quality. In the last period (2008), more than 10 years later, assemblages still maintained a moderate quality (0.55 ± 0.06). The quality of coralligenous in the last two periods (1996 and 2008) was significantly different from that of 1961 (Table 3 and Fig. 4a), even if PERMDISP results indicated a significant dispersion among samples ($p = 0.017$).

Results of PERMANOVA on coralligenous assemblages of Mesco Reef showed significant differences in the composition and abundance of taxa/groups among periods (Table 4). The SIMPER test showed that differences between 1961 and the following periods were mainly due to the disappearance of the false black coral *Savalia savaglia*, the soft coral *Alcyonium coralloides*, the sponge *Spongia officinalis* and the bryozoan *Smittina cervicornis*, matched by the increase of large hydroids and encrusting sponges (Table 5). The appearance of the alien invasive algae

Womersleyella setacea and *Caulerpa cylindracea* in 1996 and 2008, respectively, also contributed to the observed differences.

3.3 Spatial dataset

A reduction in the quality of coralligenous was observed along the gradient of human pressure, i.e. ranging from marine protected areas to high urbanised sites, considering both the effects of disturbance (Fig. 3c) and stress (Fig. 3d). However, considering sensitivity to stress and disturbance separately, a significant negative correlation with the gradient of pressure was found only considering the stress component of sensitivity (SSL) ($r = -0.68$, $p < 0.01$ with SSL index, and $r = -0.51$, $p = 0.1$ with DSL index; $n = 15$ in both cases). Coralligenous in the protected sites showed values of ISLA ranging from 0.93 ± 0.03 (Montecristo, i.e. the reference condition) to 0.70 ± 0.09 (Villasimius) (Fig. 5); most of these sites resulted in a high ecological quality, Tavolara was in a good quality and Villasimius resulted in a moderate quality. ISLA in coralligenous with low level of urbanisation ranged from 0.75 ± 0.05 (Giglio) to 0.52 ± 0.04 (Vada), all having a good quality, but Vada that resulted in a moderate quality. ISLA in the coralligenous with high level of urbanisation ranged from 0.62 ± 0.05 (Piombino) to 0.39 ± 0.04 (Civitavecchia): most sites had a moderate quality, Civitavecchia had a poor quality and Piombino just reached the good quality. Mean values of ISLA were significantly higher in protected and low urbanised sites than in high urbanised sites (Table 3 and Fig. 4b). No differences were found between protected and low urbanised sites.

Results of PERMANOVA on coralligenous assemblages in the spatial datasets detected significant differences in the composition and abundance of taxa/groups among conditions. Pair-wise test showed that differences were significant between high urbanised sites and the two other conditions but were not significant between protected and low urbanised sites (Table 4). The SIMPER test showed that differences between protected/low urbanised sites and high urbanised sites were mostly due the virtual disappearance of the erect Rhodophyta and of the Udoteaceae (*Halimeda tuna*), to

the decrease of the gorgonian *Eunicella cavolini* and to the great increase of algal turf, of the red algal genus *Peyssonnelia* and of encrusting sponges in the latter condition (Table 6).

4. Discussion

Coralligenous assemblages constitute the second most important ‘hot spot’ of species diversity in the Mediterranean after *Posidonia oceanica* seagrass meadows (Ballesteros, 2006). Estimates of the species richness found in coralligenous assemblages give a very conservative total number of species around 1670 (Ballesteros, 2006), of which at least 315 species are macroalgae (Boudouresque, 1973). Because it would be impossible to mention all the species that could be found in the coralligenous habitat, the list we compiled, according to the main literature and to our data, includes both the most characteristic taxa and a number of OTUs (Operational Taxonomic Units) that can be easily recognized in photographic samples; however, this list does not claim to be exhaustive of all the components of such a high biodiverse ecosystem and could certainly be improved in future investigations.

Besides its high biodiversity, the coralligenous is also a very complex habitat (Paoli et al., 2016) hosting a pool of organisms with different levels of sensitivity to disturbance and stress. Because of the lack of comprehensive empirical information on the interactions between benthic species and stressors (Teck et al., 2010), we applied an expert judgment method to define the sensitivity level of organisms to stress (SSL) caused by alterations in water quality, a method already used for eliciting response of marine ecosystems to anthropogenic stressors (Halpern et al., 2007). It is recognized that this method introduces some uncertainty and subjectivity in the final result (De Lange et al., 2009) that cannot be quantified; however, this is perhaps only a minor disadvantage as long as the analysis produces an estimate of relative instead of absolute sensitivity. New ecological information that will become available could always be incorporated to improve the levels of sensitivity we proposed.

The trait-based approach we used to define the sensitivity level of species to disturbance (DSL) has been shown to be more meaningful than comparisons of species richness or composition (Darling et al., 2012). Species traits provide important information about life-history strategies, which can broadly define how organisms interact with each other and with their environment. Species with small size, fast growth rates and high population turnover (e.g. hydroids, encrusting bryozoans, filamentous algae) are expected to be more resilient to disturbances, opportunistic and able to persist in unfavourable environments (Knowlton, 2001); on the contrary, large, slow-growing and long lived organisms (like most of the anthozoans usually dominant in coralligenous assemblages) are expected to be more sensitive to physical disturbances (Jackson and Hughes, 1985; Rachello-Dolmen and Cleary, 2007). Similarly, variations in individual/colony morphology and reproductive mode are thought to suggest the primary role of species as competitor, tolerant, etc. (Edinger and Risk, 2000). Observations of increasing abundances of opportunistic and resistant species on disturbed coral reefs suggested that biological traits can predict which organisms are ‘winners’ or ‘losers’ in the face of environmental change (Rachello-Dolmen and Cleary, 2007; Alvarez-Filip et al., 2011). The six biological traits we used in this first attempt to measure DSL are not comprehensive of all possible aspects of life-history strategies of benthic organisms; the trophic strategy, as well as other reproductive modalities adopted by sessile invertebrates, could also be considered. The scores of sensitivity (both SSL and DSL) to specific external physical, chemical and biological factors can be shared within a broad group of species but, sometimes, sensitivity cannot be synthesised into an univocal score that is suitable for all members of a group: 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.

The assessment of descriptors suitable to detect early signals of stress and disturbance is a main goal for ecologists, as a sudden detection of human-induced impacts may drive an effective and prompt management of coastal areas (Borja et al., 2009). In this contest, the recent European Directives WFD and MSFD (EC, 2000, 2008) stimulated the development of proper tools to

monitor the ecological quality of marine systems (Birk et al., 2012). The ecological indices we proposed in this paper may represent practical tools to discriminate disturbance and stress, an issue that has been hardly achieved in the past. In the 41% of the taxa/groups we defined, the two components of sensitivity, i.e. to disturbance and to stress, were not consistent: this means that species such as long-lived erect anthozoans (e.g. *Leptogorgia sarmentosa*, *Paramuricea clavata*, *Corallium rubrum*) may be somewhat tolerant to alteration in water quality (Cerrano et al., 2000; Garrabou et al., 2001, 2009; Coma et al., 2007; Teixidó et al., 2013) but very sensitive to disturbances such as mechanical damages and climate changes (Bavestrello et al., 1997); on the contrary, algal species such as Laminariales and Fucales may be very sensitive to stress induced by water quality alteration but resistant to mechanical damages (Piazzi et al., 2012). A more subtle distinction between stress and disturbance may also depend on the intensity and the duration of external agents and then they are named according to the effect they produce. A disturbance usually appears suddenly and affects organisms during a restricted time, at the end of which organisms can try to recover: it corresponds to a pulse impact (Bender et al., 1984). A stress can be interpreted as a "press" impact (Bender et al., 1984) that is more durable and chronic so that organisms can only adapt to this new altered situation (Montefalcone et al., 2008).

As expected, considering only the effects of stress in the 50-years long-term assessments at Mesco Reef, continuous negative effects were observed during the last 50 years on coralligenous assemblages (Parravicini et al., 2013), which accelerated during the '90 and then slowed down in the last years thanks to local management and conservation efforts undertaken in this site (Gatti et al., 2015b). Considering the effects of disturbance alone, a pulse event occurred between 1990 and 1996, from which some species were able to recover in the following years: this means that proper actions of management aimed at reducing local stress can also be effective to contrast the effects of global disturbances such as climate change. The period between 1990 and 1996 corresponds to the years of the greatest effects of global warming and consequent positive climate anomalies reported at the basin wide scale of the Mediterranean Sea (Gatti et al., 2015b; Thibaut et al., 2016), which

affected many benthic communities also leading to their disappearance: this is the case, for instance, of some species of the macroalgal genus *Sargassum* that are considered very sensitive to climate disturbances (Thibaut et al., 2016) but more tolerant to human-induced stress (García-Gómez, 2015). Finally, as climatic disturbances act at the whole basin scale, only the SSL index resulted significantly correlated to the pressure gradient in the spatial dataset.

Sensitivity to stress (SSL) and sensitivity to disturbance (DSL) must thus be considered as two different biological characteristics of organisms, notwithstanding the difficulty to glimpse a rigid distinction because of the overlap existing between these two concepts. Considering only one of the two components of sensitivity, e.g. sensitivity to stress (see for instance Cecchi et al., 2014; Piazzini et al., 2015), all the responses of organisms to environmental alterations could not be fully embraced. The integrated sensitivity level (ISL) we proposed to combine SSL and DSL into a single value may represent an effective and comprehensive measure of all the effects of recent changes experienced by marine coastal ecosystems in the Mediterranean Sea. The resulting ISLA index, based on the abundance and the integrated sensitivity of sessile macroalgae and macro-invertebrates in the whole assemblage, showed effective in detecting changes in the quality of coralligenous in the 15 sites along the gradient of human pressures and at the site of Mesco Reef through the last 50 years. Along the gradient of human pressures, differences between protected and high urbanised sites were evident, while differences between protected and low urbanised sites were not significant. These results are consistent with those obtained in other coastal habitats, such as seagrass meadows (Montefalcone et al., 2009), thus suggesting that coralligenous, although being sensitive to local pressures, such as mechanical damages, contaminants and turbidity, is also affected by large scale environmental changes, such as seawater warming and establishment of alien species. Additive and synergic effects of all these pressures caused community shifts in coralligenous and rocky reefs assemblages during the last decades (Parravicini et al., 2013; Gatti et al., 2015b). In order to manage coralligenous habitats, both local (as for instance the establishment

of marine protected areas) and large-scale efforts are needed to maintain the good ecological quality of marine ecosystems (Parravicini et al., 2012).

The differences observed in the structure and composition of coralligenous assemblages in space and time were consistent and related to changes in both macroalgae and sessile macro-invertebrates. The main differences between conditions (i.e. MPA, high urbanised and low urbanised sites) along the pressure gradient were mainly related to the increase of algal turf and of encrusting sponges and to the near disappearance of the most sensitive algae (i.e. Udoteaceae and erect Rhodophyta) and of some gorgonians in the high urbanised sites. The main differences through time (from 1961 to 2008) were mainly due to the disappearance of the most sensitive species, such as *Savalia savaglia*, *Alcyonium coralloides*, *Smittina cervicornis*, which have been replaced by large hydroids, encrusting sponges, turfs and alien algal species since the mid 1990s. *S. savaglia* and *A. coralloides* are opportunistic species growing on the axes of gorgonians, and their loss was likely due to the reduced availability of gorgonians after the mass mortality events they experienced in the 1990s (Cerrano et al., 2000). Turfs are mostly constituted by filamentous species reproducing asexually that are very tolerant and well adapted to altered environmental conditions (Connel et al., 2014). Turf-forming macroalgae enhanced their nutrient uptake in atrophic conditions and are strong competitors compared to erect species, thank to their ability to quickly recover after disturbance (Aioli, 2003). The parallel decrease of erect algae reproducing by spores was probably due to the combined effects of low light levels, inhibition of recruitment, and mechanical disturbance. Macro-invertebrates are less influenced than algae by the increase of nutrients and the decrease of light (Morganatic et al., 2001) but, under altered environmental conditions, their biodiversity declined and changes in their composition were observed (Hong, 1980, 1983; Gatti et al., 2015b). Erect bryozoans are very sensitive to water quality (Harmelin and Capo, 2002) and are considered suitable ecological indicators (Prado et al., 2008; Balata et al., 2010), whilst hydroids, encrusting sponges and encrusting bryozoans are more tolerant (Hong, 1980, 1983; Balata et al., 2005; Martinz-Crego et al., 2010; Ponti et al., 2011; Gatti et al., 2015b). Sessile invertebrates can be

damaged by high sedimentation rate, as sediments may cover organisms, clogging their filtering apparatus, and inhibit their recruitment, growth and metabolic processes (Airoldi, 2003). Thus, anatomic characteristics of filtering structures and reproductive strategies may represent key factors to determine the sensitivity of animals to disturbance induced by sedimentation. Changes in pH can influence the ability of calcareous organisms to build skeletons (Orr et al., 2005; Martin and Gattuso, 2009; Lombardi et al., 2011). Finally, sessile organisms with elevate and branching structures (e.g. gorgonians) can be easily damaged by mechanical disturbances such as fishing, recreational diving and anchoring (Sala et al., 1996; Bavestrello et al., 1997; Garrabou et al., 1998; de la Nuez-Hernández et al., 2014). These findings support the biological traits approach as a valid tool to define the component of sensitivity to disturbance.

All these patterns confirm the sensitivity of coralligenous organisms to human pressures (Piazzi et al., 2012), and highlight the suitability of these assemblages to be used as ecological indicators in monitoring survey and impact evaluation studies. Other indices have been proposed to evaluate the ecological state of the coralligenous using a biocenotic approach: the CAI index (Deter et al., 2012), the INDEX-COR (Sartoretto et al., 2014) and the ESCA index (Cecchi et al., 2014; Piazzi et al., 2015). Data obtained in this large spatial and temporal scale study allowed elaborating a range of values for the integrated sensitivity (ISL, accounting for both sensitivity to disturbance and sensitivity to stress) for the main coralligenous organisms; this scale, although not exhaustive and subjected to local patterns, could be used to improve other ecological indices currently employed in monitoring programs and based on the same approach. To embrace all the levels of complexity displayed by the coralligenous ecosystem (Paoli et al., 2016), the ISLA index may also be used in combination with other available ecological indices based on different approaches: the COARSE index (Gatti et al., 2012, 2015a), for instance, adopts a seascape approach to define the integrity of the seafloor, the EBQI index (Ruitton et al., 2014) uses an ecosystemic approach, the OCI index (Paoli et al., 2016) combines measures of structural and functional complexity. Intercalibration of these indices should be a priority task in the future monitoring plans. In addition, the rationale used

to construct the ISLA index (to combine sensitivity levels to stress and to disturbance) could be used, with appropriate adjustments, to assess the status of other benthic communities in those ecological indices (see for instance Ballesteros et al., 2007; Cecchi et al., 2014; Sartoretto et al., 2014; Piazzì et al., 2015) that adopt sensitivity of species as a descriptor of environmental quality.

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Figure captions and Table and headings

Figure 1: Scores of the Integrated Sensitivity Level (ISL, bold numbers from 0 to 9) obtained combining the standardised values of Sensitivity Level to Disturbance (DSL) and Sensitivity Level to Stress (SSL) assigned to each taxon/morphological group in the coralligenous assemblages.

Figure 2: Location of the study site of Mesco Reef (MR) for the temporal dataset, and of the 15 sites for the spatial dataset: Portofino (PO), Montecristo Island (MO), Pianosa Island (PI), Tavolara Island (TA), Capo Carbonara (CC), Vada Shoals (VA), Elba Island (EL), Argentario (AR), Giglio Island (GI), Costa Paradiso (CP), Meloria Shoals (ME), Livorno (LI), Piombino (PB), Civitavecchia (CI), Santa Marinella (SM).

Figure 3: Mean quality (\pm s.e.) of the coralligenous assemblages expressed as EQR of the values of the Sensitivity Level to Disturbance index (DSL index) (a) and the Sensitivity Level to Stress index (SSL index) (b) in the different years of the temporal dataset; box plot diagrams showing the quartiles, the median, the minimum and the maximum values of the DSL index (c) and the SSL index (d), both expressed as EQR, in the three conditions (P = protected, LU = low urbanised, HU = high urbanised) of the spatial dataset.

Figure 4: Mean quality (\pm s.e.) of the coralligenous assemblages expressed as EQR of the Integrated Sensitivity Level of coralligenous Assemblages (ISLA) index in the different years of the temporal dataset (a) and in the three conditions (P = protected, LU = low urbanised, HU = high urbanised) of the spatial dataset (b). In light grey are the conditions in good quality ($0.6 \leq \text{ISLA} < 0.8$), in dark grey is the condition in moderate quality ($0.4 \leq \text{ISLA} < 0.6$). The dotted line represents the threshold value (ISLA = 0.6) for changing from a good quality to a moderate quality. Results of one-way PERMANOVA analyses are reported: ** = $p < 0.01$; * = $p < 0.05$.

Figure 5: Mean quality (+ s.e.) of the coralligenous assemblages expressed as EQR of the Integrated Sensitivity Level of coralligenous Assemblages (ISLA) index in the 15 sites of the spatial dataset. In white are sites resulting in high quality ($ISLA \geq 0.8$), in light grey sites in good quality ($0.6 \leq ISLA < 0.8$), in dark grey sites in moderate quality ($0.4 \leq ISLA < 0.6$) and in black is the site in bad quality ($ISLA < 0.4$). The dotted line represents the threshold value ($ISLA = 0.6$) for changing from a good quality to a moderate quality.

Table 1: Scores of the Integrated Sensitivity Level (ISL) for the main taxa/morphological groups in the coralligenous assemblages studied, as obtained combining the values of sensitivity to disturbance (DSL) and of sensitivity to stress (SSL) (both standardised). In the case of alien species the ISL score is put to -1 *a priori*.

Table 2: Summary of the 6 biological traits used to classify taxa/morphological groups according to their sensitivity to disturbance (DSL). The three classes of sensitivity to disturbance (low, medium, high) are reported.

Table 3: Results of one-way PERMANOVA analyses on the ISLA index in the temporal and spatial datasets. Significant effects are in bold. df = degrees of freedom; MS = Mean Squares; Pseudo- F = PERMANOVA F ratio associated with the general multivariate null hypothesis of no differences among years; p = value of the pseudo- F statistic obtained with the Monte Carlo procedure. Year = 1961, 1990, 1996, 2008; Condition = high urbanised (HU), low urbanised (LU), protected (P).

Table 4: Results of two-way and three-way PERMANOVA analyses on composition and abundance of coralligenous assemblages in the temporal and spatial datasets, respectively. Significant effects are in bold. df = degrees of freedom; MS = Mean Squares; Pseudo- F = PERMANOVA F ratio

associated with the general multivariate null hypothesis of no differences among years; p = value of the pseudo- F statistic obtained with the Monte Carlo procedure. Year = 1961, 1990, 1996, 2008; Condition = high urbanised (HU), low urbanised (LU), protected (P).

Table 5: Results of SIMPER test showing dissimilarity (as %) between years (1961, 1990, 1996, 2008) in the abundance of taxa/morphological groups and the percentage of contribution of the main taxa/morphological groups that determine this dissimilarity.

Table 6: Results of SIMPER test showing dissimilarity (as %) between conditions (HU = High Urbanised, LU = Low Urbanised, P = Protected) in the abundance of taxa/morphological groups and the percentage of contribution of the main taxa/morphological groups that determine this dissimilarity.

Table 1.

Taxa/Groups	DSL	SSL	ISL
Alien species (e.g. <i>Caulerpa cylindracea</i> , <i>Womersleyella setacea</i>)	na	na	-1
Algal turf	6	0	0
Small hydroids	7	1	0
<i>Pseudochlorodesmis furcellata</i>	8	1	1
Siphonous with vesicle-like thallus (<i>Valonia</i> spp, <i>Codium</i> spp)	8	2	1
Encrusting sponges	8	3	1
Dyctiotales	8	3	2
Encrusting Corallinales	8	4	2
Encrusting Ochrophyta (e.g. <i>Zanardinia typus</i>)	6	6	2
<i>Peyssonnelia</i> spp	8	4	2
Perforating sponges (e.g. <i>Cliona</i> spp)	9	2	2
Large hydroids (e.g. <i>Eudendrium</i> spp)	11	1	2
Encrusting bryozoans	11	2	2
Encrusting ascidians (also epibiontic)	10	2	2
Erect corticated Ochrophyta (e.g. <i>Nereia filiformis</i> , <i>Sporochnus pedunculatus</i>)	9	6	3
<i>Flabellia petiolata</i>	8	6	3
<i>Palmophyllum crassum</i>	7	8	3
Erect corticated Rhodophyta (e.g. <i>Botryocladia</i> spp, <i>Osmundea pelagosa</i>)	9	9	4
Macroforaminifera (e.g. <i>Miniacina miniacea</i>)	11	6	4
Sponges prostrate (e.g. <i>Chondrosia reniformis</i> , <i>Petrosia ficiformis</i>)	12	4	4
<i>Parazoanthus axinellae</i>	12	4	4
Stolonifera (e.g. <i>Cornularia cornucopiae</i>)	12	6	4
Flattened Rhodophyta with cortication (<i>Kallymenia</i> spp, <i>Acrodiscus vidovichii</i>)	9	10	5
<i>Halimeda tuna</i>	9	10	5
Laminariales (e.g. <i>Phyllariopsis brevipes</i>)	10	10	5
Bushy sponges (e.g. <i>Axinella damicornis</i> , <i>Acanthella acuta</i>)	13	7	5
<i>Leptogorgia sarmentosa</i>	16	4	5
Azooxantellate solitary scleractinians (e.g. <i>Leptopsammia pruvoti</i>)	15	4	5
Bivalve molluscs	15	5	5
Large serpulids (e.g. <i>Protula tubularia</i> , <i>Serpula vermicularis</i>)	14	5	5
<i>Salmacina-Filograna</i> complex	13	6	5
Ramified bryozoans (e.g. <i>Caberea boryi</i> , <i>Cellaria fistulosa</i>)	14	5	5
Fucales (e.g. <i>Sargassum</i> spp, <i>Cystoseira</i> spp)	10	11	6
Arborescent and massive sponges (e.g. <i>Axinella polypoides</i> , <i>Sarcotragus foetidus</i>)	16	6	6
Actinians	15	7	6
<i>Eunicella cavolini</i>	16	7	6
Azooxantellate colonial scleractinians (e.g. <i>Phyllangia americana mouchezi</i>)	16	5	6
Vermetids	16	5	6
Erect ascidians	15	7	6
<i>Alcyonium acaule</i>	16	8	7
<i>Alcyonium coralloides</i>	16	9	7
<i>Corallium rubrum</i>	17	8	7
<i>Eunicella verrucosa</i>	16	7	7
<i>Paramuricea clavata</i>	16	8	7
Zooxantellate individual scleractinians (e.g. <i>Balanophyllia europaea</i>)	15	9	7
<i>Myriapora truncata</i>	17	6	7
<i>Pentapora fascialis</i>	17	8	7
<i>Savalia savaglia</i>	16	11	8
Zooxantellate colonial scleractinians (e.g. <i>Cladocora caespitosa</i>)	17	9	8
<i>Eunicella singularis</i>	16	12	9
<i>Aedonella calveti</i> , <i>Reteporella grimaldii</i> , <i>Smittina cervicornis</i> , <i>Turbicellepora avicularis</i>	17	12	9

Table 2.

BIOLOGICAL TRAITS		DSL SCORE
Growth form	Encrusting	1
	Massive/Submassive	2
	Erect/Branching	3
Reproductive mode	Asexual	1
	Sexual or both	3
Individual/Colony size	Small (<1 cm)	1
	Medium (<10 cm)	2
	Large (>10 cm)	3
Growth rate	Quick (weeks)	1
	Slow (years)	3
Bioconstruction potential	None	1
	Low	2
	High	3
Generation time	Seasonal	1
	Long-lived	3
Low sensitivity to disturbance	6-9	
Medium sensitivity to disturbance	10-14	
High sensitivity to disturbance	15-18	

Table 3.

Temporal dataset					Spatial dataset				
Source	df	MS	Pseudo- <i>F</i>	<i>p</i>	Source	df	MS	Pseudo- <i>F</i>	<i>p</i>
Year	3	1249.1	4.1762	0.009	Condition	2	702.58	6.1434	0.021
Residual	47	299.1			Residual	12	114.36		
Total	50				Total	14			
Pair-Wise Test			Groups	<i>p</i>				Groups	<i>p</i>
			1961-1990	0.418				P-LU	0.499
			1961-1996	0.001				P-HU	0.025
			1961-2008	0.015				LU-HU	0.018
			1990-1996	0.025					
			1990-2008	0.294					
			1996-2008	0.299					

Table 4.

Temporal dataset					Spatial dataset				
Source	df	MS	Pseudo- <i>F</i>	<i>p</i>	Source	df	MS	Pseudo- <i>F</i>	<i>p</i>
Year = Y	3	14015	4.7	0.001	Condition	2	1772900000	30.8	0.004
Station = St	4	7896	91.9	0.001	Site(C)	12	57539	33.1	0.001
Y × St	9	2930	34.1	0.001	Area(S(C))	15	17380	11.7	0.001
Residual	34	85			Residual	870	1477		
Total	50				Total	899			
Pair-Wise Test			Groups	<i>p</i>				Groups	<i>p</i>
			1961-1990	0.213				P-LU	0.071
			1961-1996	0.001				P-HU	0.017
			1961-2008	0.003				LU-HU	0.046
			1990-1996	0.145					
			1990-2008	0.016					
			1996-2008	0.199					

Table 5.

Taxa/Groups	Abundance	Abundance	Dissimilarity
	1961	1990	53.30
<i>Cellaria fistulosa</i>	4.73	0	6.45
<i>Agelas oroides</i>	2.47	6.0	5.51
<i>Savalia savaglia</i>	3.8	0	5.19
<i>Flabellia petiolata</i>	2.07	4.17	5.09
<i>Alcyonium coralloides</i>	3.73	2.0	4.41
Large hydroids	0	3.17	3.76
<i>Peyssonnelia rubra</i>	2.6	0	3.73
<i>Phorbas tenacior</i>	0	3.0	3.55
<i>Salmacina-Filograna</i> complex	0	3.0	3.55
<i>Spongia officinalis</i>	2.47	0	3.51
<i>Smittina cervicornis</i>	2.8	0	3.47
	1961	1996	74.08
<i>Womersleyella setacea</i>	0	8.0	8.09
Large hydroids	0	7.67	7.76
<i>Cellaria fistulosa</i>	4.73	0	4.71
<i>Pentapora fascialis</i>	4.8	0.8	4.51
<i>Axinella damicornis</i>	5.8	2.4	3.83
<i>Alcyonium coralloides</i>	3.73	0	3.39
<i>Paramuricea clavata</i>	6.27	4.2	3.33
<i>Peyssonnelia rubra</i>	2.6	0	2.73
<i>Phorbas tenacior</i>	0	2.4	2.45
<i>Haliclona cratera</i>	0	2.4	2.45
<i>Caryophyllia inornata</i>	2.67	0	2.33
	1990	1996	66.81
<i>Womersleyella setacea</i>	0	8.0	8.84
<i>Pentapora fascialis</i>	6.17	0.8	5.96
Large hydroids	3.17	7.67	5.47
<i>Peyssonnelia squamaria</i>	6.0	1.27	5.45
<i>Paramuricea clavata</i>	7.33	4.2	3.51
<i>Caryophyllia inornata</i>	3.17	0	3.0
<i>Sarcotragus foetidus</i>	3.17	0	3.0
<i>Haliclona cratera</i>	0	2.4	2.67
	1961	2008	74.28
<i>Womersleyella setacea</i>	0	8.53	8.43
<i>Axinella damicornis</i>	5.8	0.8	5.12
<i>Pentapora fascialis</i>	4.8	0	4.84
Large hydroids	0	5.33	4.58
<i>Cellaria fistulosa</i>	4.73	0	4.52
<i>Spirastrella cunctatrix</i>	0	4.53	4.19
<i>Savalia savaglia</i>	3.8	0	3.64
<i>Paramuricea clavata</i>	6.27	4.27	3.46
<i>Haliclona cratera</i>	0	4.07	3.35
<i>Leptogorgia sarmentosa</i>	1.27	2.73	3.33
<i>Alcyonium coralloides</i>	3.73	0	3.25
	1990	2008	70.31
<i>Womersleyella setacea</i>	0	8.53	8.77
<i>Pentapora fascialis</i>	6.17	0	6.25
<i>Peyssonnelia squamaria</i>	6.0	1.67	4.77
<i>Spirastrella cunctatrix</i>	0	4.53	4.36
<i>Flabellia petiolata</i>	4.17	1.27	4.17
Large hydroids	3.17	5.33	3.61

<i>Paramuricea clavata</i>	7.33	4.27	3.6
<i>Haliclona cratera</i>	0	4.07	3.5
<i>Leptogorgia sarmentosa</i>	0	2.73	3.43
<i>Sarcotragus foetidus</i>	3.17	0	2.74
<i>Caulerpa cylindracea</i>	0	2.4	2.06
	1996	2008	53.93
<i>Parazoanthus axinellae</i>	4.07	5.6	4.73
<i>Paramuricea clavata</i>	4.2	4.27	4.67
<i>Leptogorgia sarmentosa</i>	1.27	2.73	4.59
<i>Smittina cervicornis</i>	4.0	3.6	4.45
<i>Caryophyllia inornata</i>	0	3.73	4.44
<i>Haliclona cratera</i>	2.4	4.07	4.19
<i>Axinella verrucosa</i>	1.2	3.6	4.16
<i>Lithophyllum stictaeforme</i>	1.27	3.6	4.13
<i>Cliona celata</i>	0	3.6	4.11
<i>Caulerpa cylindracea</i>	0	2.4	2.73

Table 6.

Taxa/Groups	Abundance P	Abundance LU	Dissimilarity
	P	LU	78.16
Erect corticated terete Rhodophyta	23.99	2.62	28.12
Turf	6.01	15.7	22.64
<i>Peyssonnelia</i> spp	10.12	7.8	18.06
<i>Flabellia petiolata</i>	2.97	1.45	6.64
<i>Halimeda tuna</i>	4.02	0.61	6.38
<i>Eunicella cavolini</i>	2.09	1.06	4.92
Encrusting sponges	2.38	2.14	4.91
	P	HU	79.32
<i>Peyssonnelia</i> spp	10.12	29.93	30.54
Turf	6.01	25.18	25.92
Erect corticated terete Rhodophyta	23.99	0.28	20.66
Encrusting sponges	2.38	3.86	4.78
<i>Flabellia petiolata</i>	2.97	1.38	4.61
<i>Halimeda tuna</i>	4.02	0	4.12
	LU	HU	70.44
<i>Peyssonnelia</i> spp	7.8	29.93	38.94
Turf	15.7	25.18	35.69
Encrusting sponges	2.14	3.86	6.82
<i>Flabellia petiolata</i>	1.45	1.38	3.58
Erect corticated terete Rhodophyta	2.62	0.28	3.4
<i>Eunicella cavolini</i>	1.06	0.52	2.35

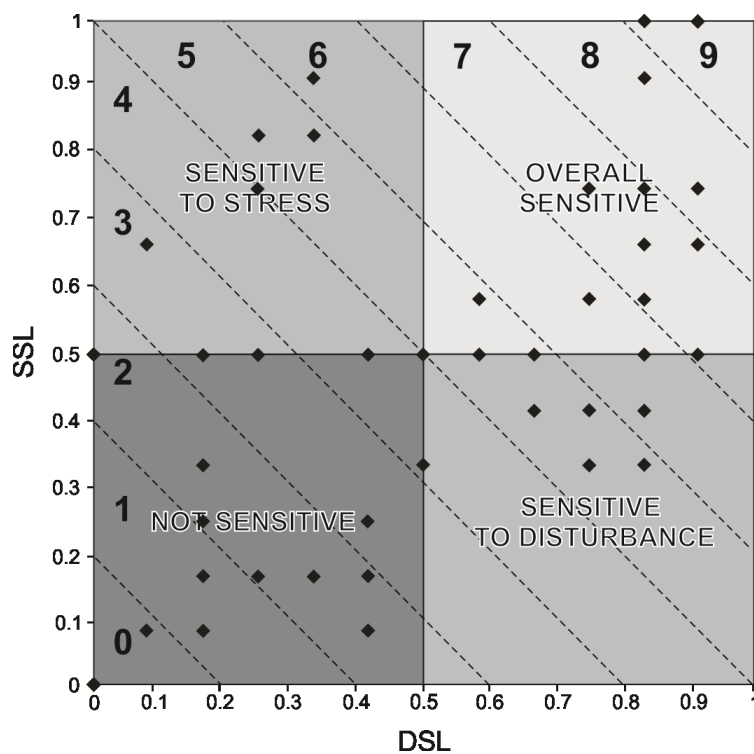


Figure 1

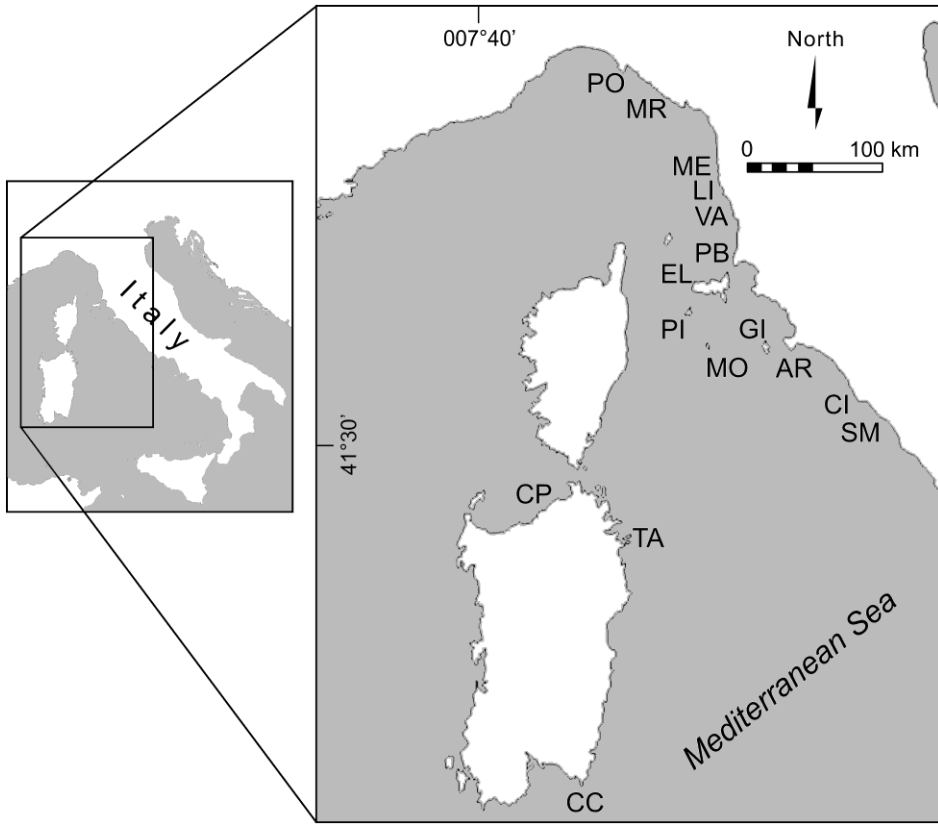


Figure 2

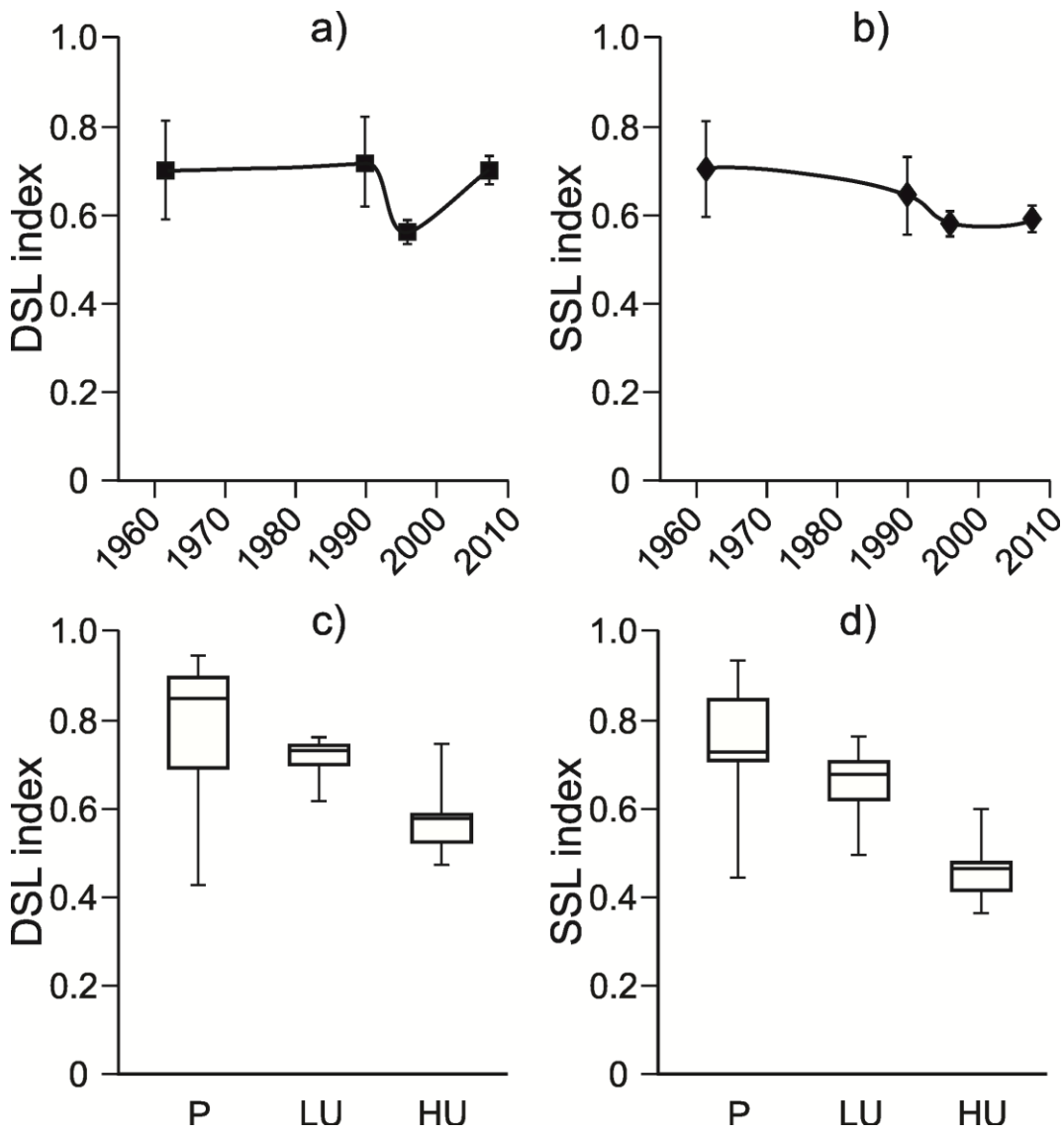


Figure 3

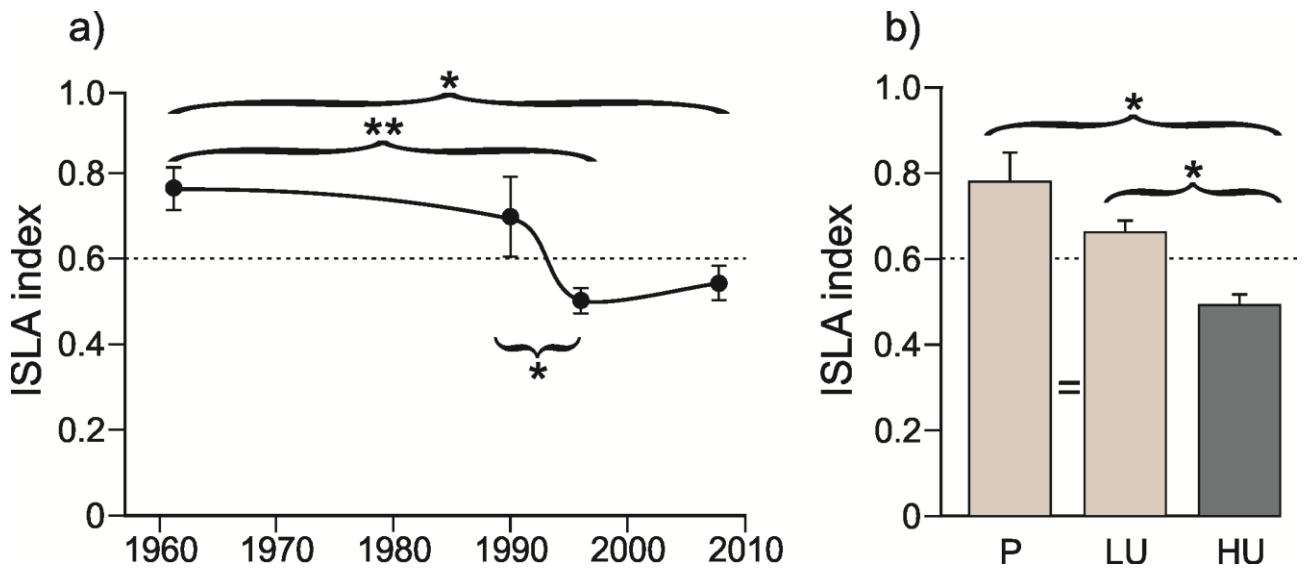


Figure 4

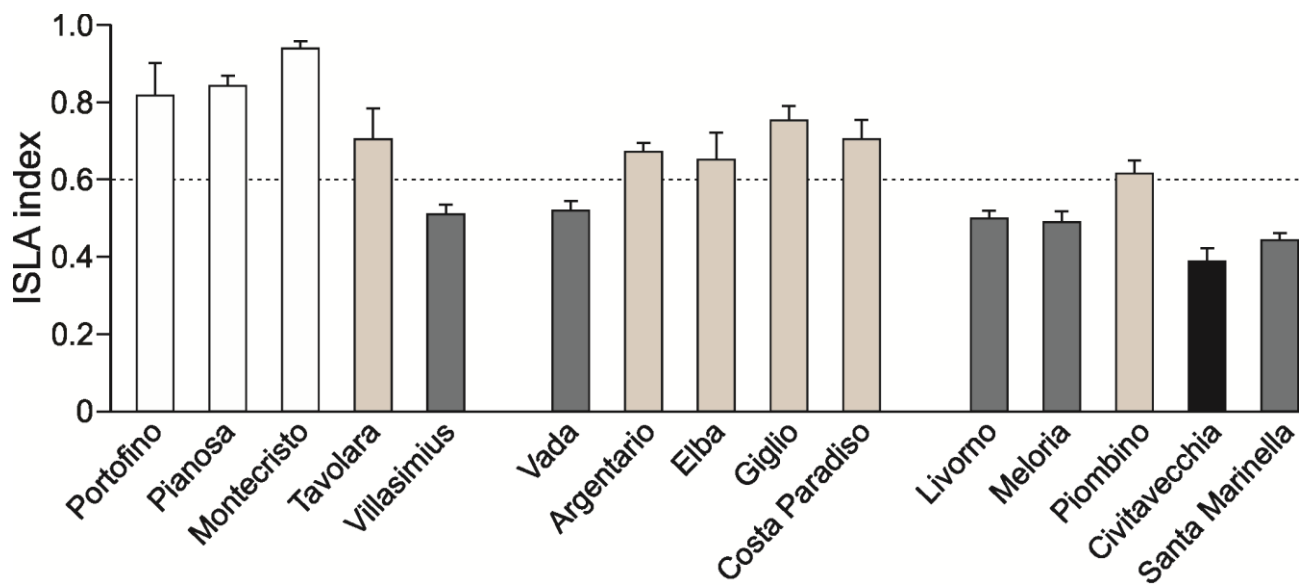


Figure 5