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Habitat Fragmentation Enhances the Difference between Natural and Artificial Reefs in an Urban Marine Coastal Tract

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Abstract: Coastal urbanization and the consequent proliferation of artificial structures greatly impact rocky reef communities, productive and diverse marine environments that play a crucial role in the functioning of broader coastal ecosystems. This study, conducted along a 7 km stretch of coastline at increasing distance from the port of Genoa (Ligurian Sea), investigated whether the alternating presence of artificial and natural reefs leads to discernible differences in the biota inhabiting these two reef types. The study area is one of the most anthropized areas of the Mediterranean Sea, exhibiting nearly 60% coastal artificialization, which severely impacts coastal ecosystems, favouring the replacement of sensitive species with more tolerant species. Ten reefs (5 natural and 5 artificial) were surveyed by scuba diving at about a 6-m depth, employing quadrats of 50 cm × 50 cm to estimate visually the percent cover of conspicuous sessile organisms. The artificial reefs hosted a similar number of species (18) to their natural counterparts (19) but exhibited a distinct community composition: the former were especially characterized by *Jania rubens* and filamentous algae, with the latter characterized by *Peyssonnelia squamaria* and *Mesophyllum lichenoides*. This difference, however, became negligible where coastal habitat fragmentation (here measured with a purposely devised Fragmentation Index) was minimal. Reducing fragmentation may therefore represent a management strategy to minimize the potential impact of artificial structures on marine biodiversity.

Keywords: coastal artificialization; infralittoral rock; sessile epibenthic communities; species richness; Fragmentation Index; port of Genoa; Ligurian Sea

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1. Introduction

Many of the world's largest cities are situated in coastal areas [1,2]. In the United States, more than 50% of the population live in coastal areas [3]; in Asia, large cities are concentrated on the coast [4]; and a similar situation concerns the entire world [5]. The human population of coastal areas worldwide is experiencing faster growth as compared to inland settlings [6]. Coastal cities are thus rapidly expanding due to increasing demand for space, the need to protect coastal infrastructures, buildings, and populations, and to support maritime traffic [7].

Urban infrastructures to support commercial, residential, and tourist activities affect coastal environments, exposing their natural habitats and the associated species and ecological processes to multifarious and profound changes [8,9]. These artificial structures, such as breakwaters, jetties, and seawalls, have become commonplace in intertidal and shallow subtidal areas, where they flank or even replace natural rocky reefs, producing a heterogeneous pattern of habitats [10]. The resulting ecosystem fragmentation may lead to reduced ecological connectivity and diversity loss [11–13].

Rocky reefs are among the most productive and diverse marine environments and play a crucial role in the functioning of broader coastal ecosystems [14]. They are essential for the provision of ecosystem services (including fishery and tourism) that the ocean ensures humans [15,16]. The replacement of natural rocky reefs with artificial reefs has been shown to alter species composition, leading to communities being dominated by opportunistic organisms [17], and thus has a negative impact on the environment [18].

Nevertheless, artificial reefs often become a newly available substrate that is colonized by marine organisms [19]. Besides being coastal defence elements [20], they are recognized as a valuable solution to deter illicit trawling, bolster fish populations, and enhance small-scale coastal fisheries [21–24]. If the primary goal of artificial reef construction is the creation of additional reef habitat for fish, it should be considered that their assemblages will likely differ significantly from those of adjacent natural reefs, also depending on the rock type of the latter compared to the materials used for the former [25]. Artificial reefs have also been employed for marine restoration, although their effectiveness in restoring ecosystems lacks well-defined ecological criteria and empirical evidence [26]. However, there is increasing evidence that the epibiota thriving on artificial reefs is often distinct from that found on natural reefs [2], not only in terms of epibenthic assemblage composition but also in terms of trophic function: suspension feeding typically dominates natural reefs, while within artificial reefs, there may be an ascendency of carnivory [27].

Many studies have demonstrated the negative effects that artificial reefs exert on the native regional biota: for instance, the lower physical complexity of artificial substrates implies reduced availability and spatial distribution of microhabitats, which would create small-scale spatial heterogeneity and hence higher biodiversity [28]. Manipulative field experiments demonstrated that the deployment of artificial reefs produced and effect on marine biodiversity similar to a large disturbance that created free space [29].

In the Mediterranean Sea, the use of artificial reefs dates back 3000 years [30] and has significantly altered the coastline, creating armoured shorelines out of shallow sedimentary habitats [31]. In several regions of Italy, France, and Spain, formerly characterized by rocky reefs [14,32], artificial reefs cover more than 45% of the coastal strip [2]. Concerns about their ecological impacts arose in the 1970s [33,34]; besides fragmenting native species populations, artificial reefs favour the spread of invasive exotic species, either algae or invertebrates, brought in by maritime traffic [35,36].

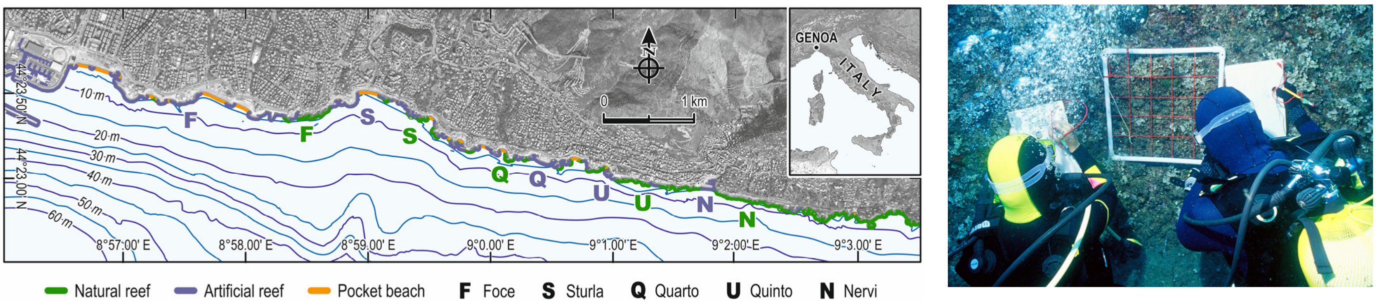
The Ligurian Sea is one of the most anthropized areas of the Mediterranean Sea [37]; coastal artificialization, estimated to reach 60%, impacts coastal ecosystems by favouring the replacement of species sensitive to human pressures with more ruderal species [38]. The coastal stretch of the city of Genoa (NW Italy), in particular, is highly urbanized [39]. The present study focuses on examining whether the alternating presence of natural and artificial reefs leads to discernible differences in the sessile epibenthic communities inhabiting these two types of substrates, along a gradient of distance from the port.

2. Materials and Methods

2.1. Study Area and Field Activities

This study is part of an environmental impact assessment planned in view of the construction of a new breakwater in Genoa Harbour, one of the largest ports of the Mediterranean Sea and a major hub of maritime traffic. The activities were conducted along 7 km of the eastern coast of Genoa, in five areas situated at increasing distance from the port and named according to the locales of Genoa that they front. From west to east, they are (Figure 1a) Foce (F), Sturla (S), Quarto (Q), Quinto (U), and Nervi (N). In each locale, both natural and artificial reefs were sampled to investigate differences in their quali–

quantitative composition and species richness of their communities. Artificial reefs were represented by groynes and coastal defences made of quarry rocks.



(**a**) (**b**)

Figure 1. Study area along the eastern coastline of Genoa (NW Italy); the five locales studied (Foce, Sturla, Quarto, Quinto, Nervi), with the three different types of coastline (natural reefs, artificial reefs, pocket beaches), are indicated (**a**). Two diving scientists surveying a 50 cm × 50 cm quadrat on a (sub)vertical rock (**b**).

The coastline in the study area is fragmented, with alternation between pocket beaches, natural reefs, and artificial reefs; moving eastward from the port, coastal urbanization diminishes [40,41], correlating with an increasing prevalence of natural reefs (Figure 1a).

In each of the 10 reefs surveyed (5 natural and 5 artificial, both bordering the shore), three visual replicates were taken, employing quadrats of 50 cm × 50 cm (i.e., 0.25 m^2) divided into 25 smaller quadrats (Figure 1b). Quadrats of this size have been shown to represent a good compromise between underwater handling control and sampling representativeness [42]. Although a sample size that could be recommended universally does not exist [43], early experiences in the Mediterranean indicated that quadrats of 20 cm × 20 cm, distinctly smaller than the ones used in the present study, are adequate for the analysis of shallow algal-dominated rocky reef communities [44,45]. Obviously, the problem of the minimal area is of a practical nature and concerns a cost–benefit analysis between the information retrieved and the sampling effort [46].

Specifically, in the Genoa reef survey, a square frame made of plastic material was placed on (sub)vertical rocks at about a 6-m depth, and two diving scientists estimated visually the percent cover of conspicuous sessile organisms, writing data on a diving slate. A depth of 6 m was considered the best option according to the observed bathymetric zonation of the algal communities in the area. As typical for Mediterranean infralittoral rocky reefs [47,48], strong zonation occurs in the study area: preliminary surveys showed the dominance, in the first few meters of depth, of the brown alga *Dictyota spiralis* in sheltered situations and of the red algae *Jania virgata* and *Laurencia* sp. in exposed or semi-exposed situations. It has been observed that the effect of wave exposure may eclipse the difference between natural and artificial reefs [49]. On the other hand, at about 8 m both natural and artificial reefs end on a sandy bottom. Previous studies on algal-dominated rocky reefs in the Mediterranean were also carried out at comparable depths [50–53], among others.

The field work was carried out in March 2023 to avoid the proliferation of ephemeral summer species, whose blooms might blur the difference between natural and artificial reefs. As typical for the whole Ligurian Sea, in March strong counterclockwise circulation causes the upwelling of deep waters, which supports high primary production in spring, leading to mesotrophic conditions that contrast with the oligotrophic conditions of the summer and winter months [37]. The seawater temperature of the Ligurian Sea in March is still close to winter temperatures: in 2023, in particular, the sea surface temperature averaged 12.9 °C [54].

2.2. Data Management

The proportion of natural reefs, artificial reefs, and pocket beaches along the coastline of each locale was calculated from aerial photographs taken in June 2023 available on Google Earth [55]. To measure the habitat fragmentation of each locale's coastal tract, a Fragmentation Index (FI) was devised based on Simpson's Dominance Index [56] and applied to the three coastline features (pocket beaches, natural reefs, and artificial reefs):

$$FI = \Sigma\,(n_i/N)^2$$

where FI is the Fragmentation Index, Σ is the summation from 1 to 3 (number of coastline features), and n_i is the total linear length of the ith feature in the locale. The FI ranges from 0 to 1, where 0 is the maximum fragmentation (the three features being equally abundant) and 1 is the absolute dominance of one feature.

Differences in species richness, expressed as the plain number of species [56] in natural and artificial reefs, were tested using two-way ANOVA. Percent cover data of conspicuous sessile organisms were organized into a matrix [(locale × reef type) × species], which was subjected to non-metric multidimensional scaling (nMDS) based on the Bray–Curtis index after arcsine transformation [57]. A two-way permutational multivariate analysis of variance (PERMANOVA) was applied to highlight potential compositional differences in the rocky reef communities among the locales and between reef types (natural vs. artificial). A SIMPER analysis, always based on the Bray–Curtis index [57], was applied to identify the taxa that contributed most to the difference (whose significance was tested using Student's t) between natural and artificial reefs. The difference in the qualitative (species occurrence) and quantitative (cover) composition of the communities in the two reef types (natural vs. artificial) in each locale was measured using Euclidean distances [57]; the Euclidean distances between the two reef types were then compared to the FI to see whether habitat fragmentation within locales may affect the distinction between natural and artificial reefs. All the analyses were performed using the free software PaSt 4.03 [58].

3. Results

The coastline of Genoa exhibited a noteworthy difference in the proportion of coastline features within the individual locales: the westernmost locales, close to Genoa port (e.g., Foce and Sturla), had a greater proportion of artificial reefs (43% and 31% of the coastline) and pocket beaches (both 27% of the coastline) than the easternmost locales, such as Quinto and Nervi, where rocky reefs occupied 69% and 73% of the coastline, respectively (Figure 2a). Consistently, the FI showed a nearly continuous trend of decrease from west to east; in particular, the FI of Nervi was distinctly lower than that of all the remaining locales (Figure 2b). The average difference between assemblage composition and cover in natural and artificial reefs within each locale, expressed as Euclidean distance, similarly decreased the further away from Genoa one moved, to reach a minimum in Nervi (Figure 2c).

A total of 22 taxa were found, of which 19 were identified to the species level and two to higher levels only (class or family); filamentous algae not identifiable visually underwater were collectively named turf, a morphological group without taxonomic connotation (Table 1). Red algae were the most represented taxon, with 8 species: among them, *Ellisolandia elongata* exhibited the highest percent cover, followed by *Peyssonnelia squamaria*. Brown algae were represented by 4 species, with *Halopteris scoparia* reaching comparatively high cover. The cover by sessile invertebrates was almost negligible, although sponges were speciose. Turf reached high cover, especially on artificial reefs.

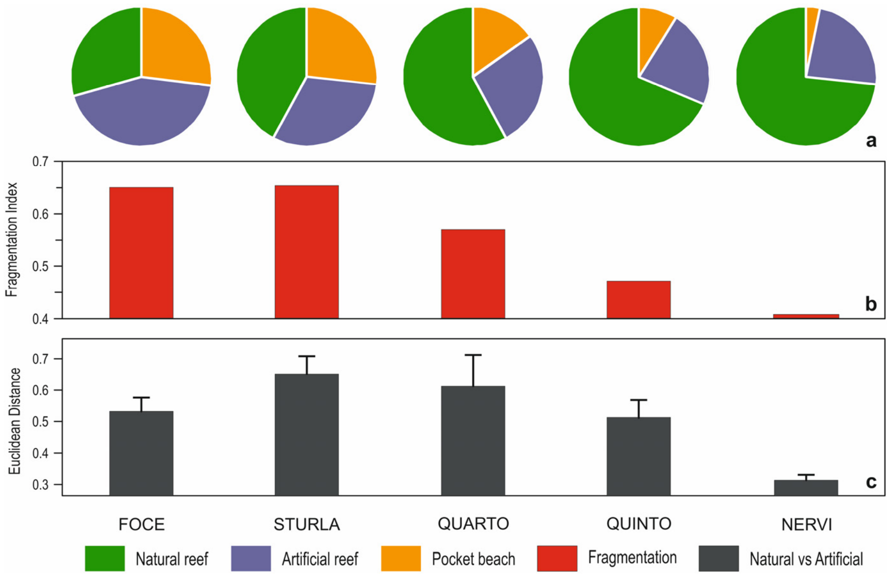
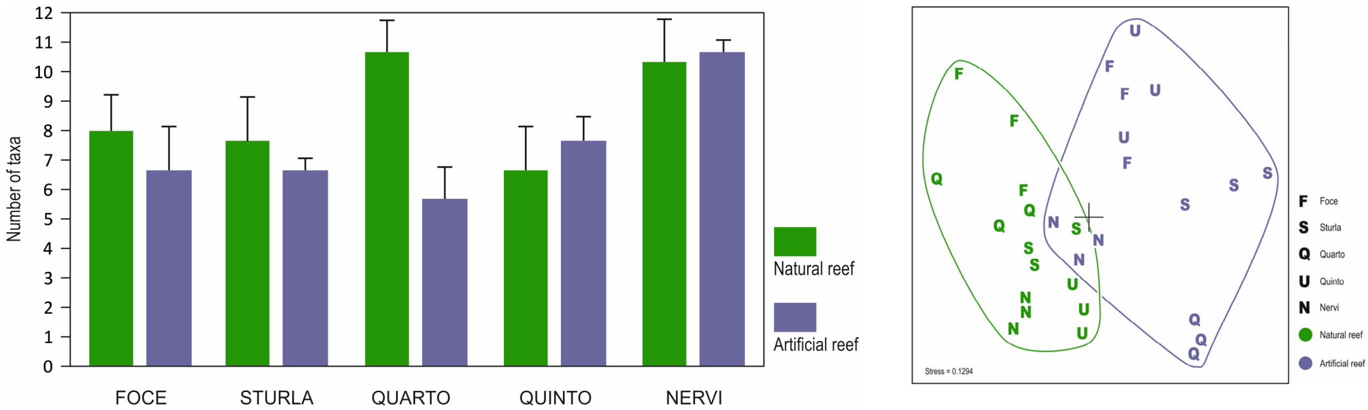


Figure 2. Pie charts of the proportion of the three coastline features (natural reef, artificial reef, and pocket beach) in each Genoa locale (**a**); the resulting Fragmentation Index (**b**); and the mean (+standard error) Euclidean distance between natural and artificial reefs in each locale (**c**).

Table 1. List of the 22 taxa recorded in the quadrats, ordered alphabetically within phyla or morphological groups.

Ochrophyta
Cystoseira compressa (Esper) Gerloff and Nizamuddin, 1975
Dictyota dichotoma (Hudson) J.V.Lamouroux, 1809
Halopteris scoparia (Linnaeus) Sauvageau, 1904
Padina pavonica (Linnaeus) Thivy, 1960
Rhodophyta
Amphiroa rigida J.V.Lamouroux, 1816
Ellisolandia elongata (J.Ellis and Solander) K.R.Hind and G.W.Saunders, 2013
Asparagopsis armata Harvey, 1855 (*Falkenbergia rufolanosa* stadium)
Jania rubens (Linnaeus) J.V.Lamouroux, 1816
Lithophyllum incrustans Philippi, 1837
Mesophyllum lichenoides (J.Ellis) Me.Lemoine, 1928
Peyssonnelia squamaria (S.G.Gmelin) Decaisne ex J.Agardh, 1842
Sphaerococcus coronopifolius Stackhouse, 1797
Turf
Filamentous algae indet.
Porifera
Chondrosia reniformis Nardo, 1847
Cliona celata Grant, 1826
Crambe crambe (Schmidt, 1862)
Ircinia oros (Schmidt, 1864)
Ircinia variabilis (Schmidt, 1862)
Cnidaria
Aiptasia mutabilis (Gravenhorst, 1831)
Hydrozoa indet.
Annelida
Protula tubularia (Montagu, 1803)
Serpulidae indet.

There was little difference in species occurrence between the natural and artificial reefs: four taxa (*Aiptasia mutabilis*, *Amphiroa rigida*, *Padina pavonica*, and *Sphaerococcus coronopifolius*) were exclusive to natural reefs and three (*Asparagopsis armata*, *Cliona celata*, and Serpulidae) to artificial reefs, while the vast majority of taxa (15) were common to both reef types. The species richness, in terms of the total number of taxa, was similar in both reef types, with 19 in natural reefs and 18 in artificial reefs. The species richness within locales was also similar (Figure 3a), with the exception of Quarto, where natural reefs were significantly richer than artificial reefs (t = 3.274, p = 0.031). The two-way ANOVA indicated that the number of taxa was not different between reef types (19 species on natural reefs, 18 on artificial ones), while the difference among locales was very significant (Table 2); the interaction between reef type and locale was significant due to the results of Quarto.



(**a**) (**b**)

Figure 3. Species richness (expressed as mean number of taxa + standard error) on natural and artificial reefs in each Genoa locale (**a**). Ordination model from nMDS of observation points corresponding to natural or artificial reefs in the Genoa locales (**b**).

Table 2. Results of two-way ANOVA on conspicuous sessile species richness according to reef type (natural vs. artificial) and Genoa locale. SS = sum of squares, Df = degrees of freedom, R^2 = determination coefficient, F = Fisher's F, P = probability, ns = not significant, ** = very significant; * = significant.

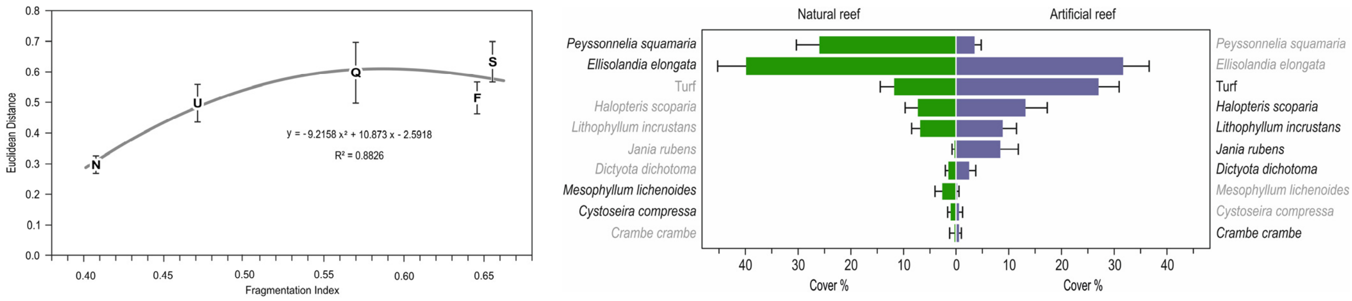
Source	SS	Df	R^2	F	*P*
Reef type	10.8	1	10.8	4	0.05927 ns
Locale	48.5333	4	12.1333	4.494	0.009412 **
Interaction	32.5333	4	8.13333	3.012	0.04263 *
Within	54	20	2.7		
Total	145.867	29			

Multivariate analysis (nMDS) ordered the observation points in two groups corresponding to the two reef types, with the points representing the natural reefs clustering on the left side of the graph, while those belonging to artificial reefs clustered on the right; the artificial reef points for Nervi, however, were an exception, being closer to the natural reef points than to the artificial reef points of the other locales (Figure 3b).

PERMANOVA evidenced highly significant differences in the quali–quantitative composition of the sessile assemblages between natural and artificial reefs; differences among locales were significant, and so were the interactions among reef types and locales (Table 3). Significant interactions were attributable to the artificial reefs of Nervi being more similar to natural reefs. Comparing the Euclidean distances between reef types with the FI for each locale clearly showed that natural and artificial reefs were more similar to each other in the presence of low habitat fragmentation (Figure 4a); in the case of Nervi, in particular, the coastline is almost completely represented by natural reefs (Figure 1a).

Table 3. Results of PERMANOVA on rocky reef communities according to reef type (natural vs. artificial) and Genoa locale. SS = sum of squares, Df = degrees of freedom, R^2 = determination coefficient, F = Fisher's F, *P* = probability, *** = highly significant, * = significant.

Source	SS	Df	R^2	F	*P*
Reef type	0.734667	1	0.73467	8.7115	0.0001 ***
Locale	0.64	4	0.16	1.8972	0.0312 *
Interaction	0.692	4	0.173	2.0514	0.0199 *
Residual	1.68667	20	0.084333		
Total	3.7533	29			



(**a**) (**b**)

Figure 4. Correlation of the difference (expressed as Euclidean distance) between natural and artificial reefs with the Fragmentation Index for each Genoa locale (**a**). Percent cover of the 10 taxa with non-nil contribution to the difference between natural and artificial reef communities, according to SIMPER analysis; species names are written in black or grey according to their reef type (natural vs. artificial) preference (**b**).

The SIMPER analysis identified 10 taxa that contributed to community differences between natural and artificial reefs; the contribution of the remaining 12 species was nil (Table 4). The species *Peyssonnelia squamaria*, *Ellisolandia elongata*, *Mesophyllum lichenoides*, and *Cystoseira compressa* reached higher cover in the natural reefs, while turf, *Halopteris scoparia*, *Lithophyllum incrustans*, *Jania rubens*, *Dictyota dichotoma*, and *Crambe crambe* had higher cover in the artificial reefs (Figure 4b). However, the difference was significant only for *P. squamaria*, turf, *J. rubens*, and *M. lichenoides*, but the latter was rather scarce in both reef types (percent cover = 2.7 ± 1.14 in natural reefs and 0.3 ± 0.21 in artificial reefs).

4. Discussion

All the epibenthic sessile assemblages studied along a gradient of urbanization from the port of Genoa towards the east belong to a community type known in the Mediterranean Sea as ESEPA, or "Exposed or Semi-Exposed water Photophilic Algae" [59], typically considered as part of a wider Photophilic Algae biocoenosis [60]. In all five locales of Genoa surveyed, ESEPA was exemplified by the dominance of the coralline alga *Ellisolandia elongata* on both the natural and artificial reefs. The mussel *Mytilus galloprovincialis*, once abundant in these reefs [40], was not observed during the 2023 survey. Between 2003 and 2013, *M. galloprovincialis* virtually disappeared from the shallow infralittoral reefs of the Ligurian Sea [53]. A similar decline in recent decades has been observed in other Italian seas, and a possible reason for this has been identified in sea water warming [61,62]. Reduced recruitment of this species on urban shores has been observed elsewhere [63].

Table 4. Contribution of the 22 taxa to the similarity between natural and artificial reefs according to SIMPER analysis (based on Bray–Curtis index). For the 10 taxa that provided a non-nil contribution, the significance of the difference is provided (Student's test). NAT = natural reefs, ART = artificial reefs, dissim = dissimilarity, contrib % = percent contribution, m = mean, se = standard error, n = number of cases, t = Student's t, *P* = probability, ns = not significant, *** = highly significant, ** = very significant, * = significant.

				NAT		ART				
		Dissim	**Contrib %**	**m**	**se**	**m**	**se**	**n**	**t**	***P***
1	*Peyssonnelia squamaria*	13.41	25.41	26.0	4.27	3.6	1.23	15	5.041	0.000 ***
2	*Ellisolandia elongata*	11.52	21.84	39.9	5.32	32.5	4.79	15	1.034	0.310 ns
3	Turf	9.63	18.25	11.8	2.40	27.7	3.75	15	−3.571	0.001 **
4	*Halopteris scoparia*	6.71	12.71	7.3	2.18	13.5	4.05	15	−1.348	0.188 ns
5	*Lithophyllum incrustans*	4.26	8.08	6.9	1.51	9.1	2.54	15	−0.745	0.463 ns
6	*Jania rubens*	4.18	7.92	0.4	0.28	8.6	3.40	15	−2.404	0.023 *
7	*Dictyota dichotoma*	1.05	2.00	1.5	0.36	2.6	1.17	15	−0.899	0.377 ns
8	*Mesophyllum lichenoides*	1.03	1.94	2.7	1.14	0.3	0.21	15	2.036	0.048 *
9	*Cystoseira compressa*	0.64	1.21	1.0	0.48	0.6	0.55	15	0.548	0.588 ns
10	*Crambe crambe*	0.34	0.65	0.4	0.70	0.6	0.32	15	−0.260	0.797 ns
11	*Protula tubularia*	0	0	0.5	0.20	0.2	0.12	15		
12	*Ircinia oros*	0	0	0.4	0.16	0.2	0.15	15		
13	*Chondrosia reniformis*	0	0	0.4	0.22	0.1	0.07	15		
14	*Sphaerococcus coronopifolius*	0	0	0.4	0.24	0.0	0.00	15		
15	*Amphiroa rigida*	0	0	0.2	0.21	0.0	0.00	15		
16	Hydrozoa	0	0	0.1	0.06	0.1	0.07	15		
17	*Padina pavonica*	0	0	0.1	0.10	0.0	0.00	15		
18	*Ircinia variabilis*	0	0	0.1	0.07	0.1	0.05	15		
19	*Asparagopsis armata*	0	0	0.0	0.00	0.1	0.07	15		
20	Serpulidae	0	0	0.0	0.00	0.1	0.10	15		
21	*Aiptasia mutabilis*	0	0	0.1	0.07	0.0	0.00	15		
22	*Cliona celata*	0	0	0.0	0.00	0.1	0.07	15		

Apart from the overall dominance by *E. elongata*, a species widespread in all Mediterranean shallow-water rocky reefs [64], there were important differences in the species composition between the natural and artificial reefs. The former were especially characterized by *Peyssonnelia squamaria* and *Mesophyllum lichenoides*, two important basal species typical of well-structured algal communities [65,66]. In the latter, the main taxa were turf, an ensemble of opportunistic filamentous algae [67], and *Jania rubens*, an epiphytic or epilithic species widespread in many shallow-water rocky habitats [68,69]. Such a contrast suggests that the community settled on artificial reefs tends to remain in a pioneer state as compared to the more mature ones found on natural reefs [70,71]. Early studies on the colonization of artificial structures in the NW Mediterranean indicated that it takes approximately 3 years for the community to reach a mature stage in terms of both biomass [72] and species composition [73,74]. Similar experiences in other seas, however, have shown that climax communities were reached in 5 to 20 years [75–77], but the differences between natural and artificial reefs have been observed to persist even for much longer times [71,78,79]. At St. Eustatius (eastern Caribbean), no significant difference in the density of coral-associated fauna was found between a centuries-old manmade structure and the nearest natural reef [49], notwithstanding differences in relief rugosity and surface structure, which are also known to exert an important influence on the entire epibenthic community [52,80]. In the Genoa area, groynes and seawalls have been deployed for a long time (>20 years) but are regularly renovated with new boulders (Figure 5), so they are likely to host a mosaic of communities in different successional stages. The epibenthic assemblage structure and recruitment differed according to rock type (sandstone vs. basalt) in Sydney Harbour [81]. The natural rock of the Genoa area is marly limestone [82], while the artificial reefs are made of serpentinite quarry rock [83]. Field experiments in the Ligurian Sea demonstrated that shallow-water epibenthic communities on serpentinites are prevented from reaching a mature condition, with red and brown algae remaining less developed: this rock, therefore, has been considered an inhibiting substratum [52].

Figure 5. A pontoon adding new boulders to an already existing artificial reef at Quarto. The outer port of Genoa is visible in the background.

Nervi, however, represented an outstanding exception, as the artificial reefs there exhibited a greater degree of similarity to their natural counterparts than to all the remaining artificial reefs in the other Genoa locales. Nervi is the only locale where both natural and artificial reefs exhibited some cover of *Cystoseira compressa*, a canopy-forming species functioning as an ecosystem engineer which plays a fundamental role in the maintenance of the understory assemblage [84–86]. The loss of *Cystoseira* canopy in urban marine coastal habitats is known to lead to assemblages dominated by the more stress-tolerant *Ellisolandia elongata* [87]. The occurrence of *Cystoseira* in Nervi may have been favoured by the high predominance (73%) of natural reefs there. Greater habitat fragmentation in the other Genoa locales may, on the contrary, hamper ecological connectivity, thus favouring the settlement of more ubiquitous and generalist species on artificial reefs [14,88]. Thus, habitat fragmentation is likely to enhance the difference between natural and artificial reefs, with the colonization of the latter being influenced by the regional species pool from surrounding habitats.

Notwithstanding the expectation that artificial reefs host a reduced species richness [89], no significant difference in species number was observed between the two reef types in Genoa. Only at Quarto were natural reefs richer than artificial reefs, due to the occurrence in the former of a number of otherwise rare species with negligible cover.

Artificial reefs are said to represent stepping stones for the proliferation of alien species [90,91], but our study revealed the presence of just one non-native species in the artificial reefs of Quarto and Nervi: *Asparagopsis armata* (*Falkenbergia rufolanosa* stadium), naturalized for several decades in the Mediterranean Sea [92]. This dearth of alien species may be due to the fact that the artificial reefs were made of natural rock, not concrete or other man-made materials, but also to the season when the survey was conducted: most alien species proliferate especially in summer; this is the case, for instance, for *Caulerpa cylindracea* [93], whose resting stolonal stages, however, may persist within turf [94], thus escaping attention during visual surveys.

5. Conclusions

The present study examined the difference between the sessile epibenthic communities colonizing natural and artificial reefs along an urbanization gradient. The main results were twofold. First, contrary to previous experiences in other areas [95,96], the artificial reefs of Genoa were not characterized by a lower species richness than the natural ones and did not represent an elective substrate for the settlement and propagation of alien species. Second, the persistent difference in community composition between natural and artificial reefs pointed out in many papers [97–99] was reduced where the artificial reefs were located in a mostly natural context: the proximity of the regional species pool appeared therefore more important than the age of the artificial reefs [77].

If confirmed by further studies, this result may be of interest for marine spatial planning. Considering the ever-growing need for coastal defences in urban areas, it is imperative to mitigate the potential impact of artificial structures on biodiversity [100]. Avoiding excess habitat fragmentation, the artificial structures may naturalize more quickly, thus providing a virtuous example of nature-friendly coastal management.

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