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Monitoring of ichthyic fauna in artificial reefs along the Adriatic coast of the Abruzzi Region of Italy

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Summary

With the support of European Community funds, three submerged artificial reefs composed of concrete cubes, bell-shaped modules and natural rocks were deployed along the Adriatic coast of the Abruzzi Region to increase the fish population and to prevent illegal trawling. The Provincial governments of Teramo and Pescara requested the *Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise 'G. Caporale'* to monitor nectobenthic populations. Three sampling operations were conducted each year for each artificial reef. The authors present the results of a study conducted between 2005 and 2007, comparing the catches from the artificial reefs with those from the control sites using several diversity indexes. Artificial reef areas revealed greater species diversity and richness than the control sites. This study demonstrates the value of artificial reefs in response to the problem of low income, non-commercial fisheries as well as to the issue of over-exploitation of halieutic resources. In addition, the authors suggest that artificial reefs may be capable of activating habitat diversification processes that will increase biodiversity.

Keywords

Abruzzi, Adriatic Sea, Artificial reef, Biodiversity, Fish, Fishery, Italy, Reef.

Introduction

In contrast with natural breakwaters that preserve the coast from erosion, artificial reefs are composed of natural (stones, trunks, etc.) or artificial (concrete, reinforced concrete, coal ash) objects that are deployed on sandy, muddy or sandy and muddy sea beds to create a diversification element on the flat and original habitat and to enhance the fishery resources of ecosystems (18). Reefs have been shown to be effective in promoting the fish and larval biomass of the colonisation of sessile organisms of a newly available artificial area. This rapid epifaunal colonisation acts as food for species of other fish and shellfish for which reefs provide a good habitat (13). Colonisation involves both autochthonous and allocthonous species. The creation of an artificial reef offers numerous advantages, including the following:

- prevention of illegal trawling (13)
- protection and development of water resources, including the commercial fishery trade
- enhancement of quantities of available fish in adjacent areas and protection of biodiversity
- use of artificial reef areas for breeding, small-scale fisheries and sports fishing.

European Union (EU) and Italian artificial reef development dates back to the 1960s (3, 4, 5, 6,

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7, 8, 9, 10, 13). From 1970 to date, in response to problems experienced along coastal areas, requirements of fisheries and ecosystems, artificial reefs were also created in other non-European countries such as Israel, Malta and Russia (13, 18, 21).

According to EU fund DOCUP – PESCA 2000/2006 3.1.: Protection and development of water resources (1), in agreement with the current Common Fisheries Policy, the objectives of our study were to analyse the effects of artificial reefs along the Adriatic coast of the Abruzzi Region in regard to the prevention of illegal trawling, the increase of marine ecosystem complexit, development of novel biomass and seasonal and changing of reef communities.

Materials and methods

Deployment of artificial reefs and modules

Three artificial reef systems are situated along the Adriatic coast of the Abruzzi Region, opposite the Cologna, Pineto (Torre del Cerrano) and Pescara municipalities. They were deployed on a flat sandy/muddy sea bed, without natural rocks or other formations of ecological interest, in a rectangular area with the major sides parallel to the coast, at a distance of 5 km (Fig. 1). The geographic coordinates of perimetric points of each artificial reef are given in Table I.

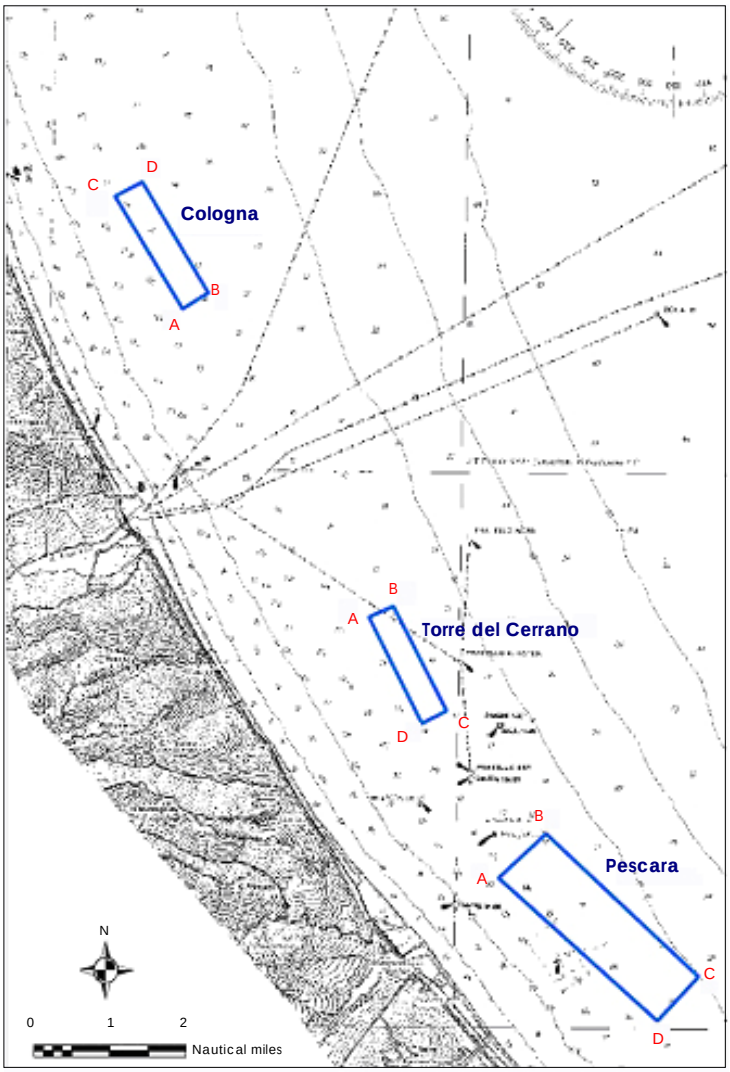


Figure 1
Location of the artificial reefs off the coast of the Abruzzi region on nautical chart No. 34

Table I
Geographic coordinates of perimeter points on the artificial reef sites

Artificial reef site	Perimeter points	Latitude	Longitude
Pescara (area of 13.86 km²)	A	42°32, 720' N	014° 11, 000' E
	B	42° 33, 530' N	014° 12, 150' E
	C	42° 31, 000' N	014° 15, 100' E
	D	42° 30, 180' N	014° 14, 900' E
Torre del Cerrano (area of 4 km²)	A	42° 37, 400' N	014° 07, 750' E
	B	42° 37, 600' N	014° 08, 350' E
	C	42° 35, 800' N	014° 09, 200' E
	D	42° 35, 500' N	014° 09, 080' E
Cologna (area of 4 km²)	A	42° 42, 920' N	014° 03, 110' E
	B	42° 43, 210' N	014° 03, 740' E
	C	42° 44, 920" N	014° 01, 430' E
	D	42° 45, 050' N	014° 02, 090' E

Points A, B, C and D can be seen in Figure 1

Pescara

The artificial reefs in Pescara are composed of 268 concrete, bell-shaped blocks, 2 m high, with external stainless steel bars and holes of different diameters. Each module weighs 4 900 kg, has a surface area of 6.91 m² for benthos colonisation for a total reef surface of 1 852 m². The modules were placed in such a way as to avoid illegal trawling with a quincunx pattern on 350 m mesh size. In particular, on the open sea side and along the orthogonal side of the artificial reef area, the blocks were deployed at a distance of less than 175 m. In the central area, 17 'oases' were created; these were composed of groups of seven bell-shaped blocks, at a distance of 5-10 m from each other. The lay-out of the Pescara reef bell-shaped modules is shown in Figure 2.

Torre del Cerrano and Cologna

As this method had already proved successful in the artificial reefs of the Adriatic Sea (8, 9, 12), 516 concrete cubic blocks (1 × 1 × 1 m) were placed in both Torre del Cerrano and Cologna. Perimetral blocks had a metallic structure at the top of the cubes for anti-trawling purposes. Pyramid-shaped structures were built with concrete cubic blocks and placed with second and third category natural rocks, forming 18 truncated cone-shaped

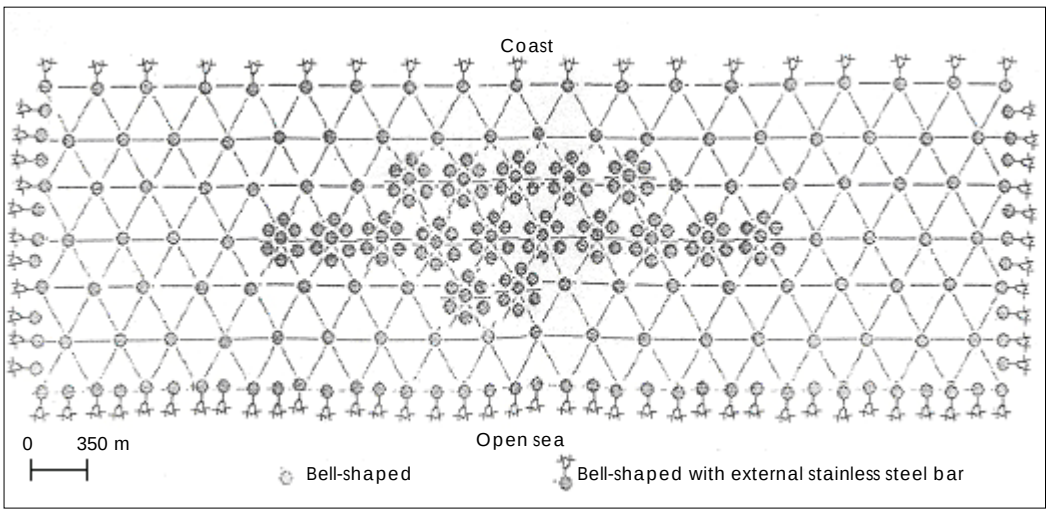


Figure 2
Positioning in staggered rows of the concrete bell-shaped modules of the Pescara site

structures 3 m high, with a 10 m base diameter and a plateau diameter of 3 m. Blocks had rough surfaces to encourage larval settlement of sessile organisms, and concave holes and pitted surfaces on lateral sides to allow marine life to take possession of different habitats. The disposition of the blocks was engineered in order to make the artificial reefs impenetrable to illegal trawling.

Figure 3 shows the placing of natural rocks and concrete bell-shaped modules in the Torre del Cerrano and Cologna sites.

Data collection

Two sampling sites for the Torre del Cerrano and Cologna artificial reef sites were identified; the first was in the central area (central point), the second had the same geographic and morphological characteristics as a control site without artificial reefs and was the same distance from the coast. Another sampling point was added to the Pescara site, towards the northern side of the reef.

With the assistance of small-scale fishermen, both artificial reefs and control sites were monitored with a 'barracuda' net (length 500 m; height 2 m; 34 mm inner mesh size). Nets were set from dusk to dawn as a routine fishing procedure.

The fishing survey was conducted from 2005 to 2007 with three samplings per year on each reef. The sampling dates for each site are presented in Table II. Samples were submitted to the laboratory in refrigerated conditions and were measured and identified.

Furthermore, samples were collected yearly by scuba divers to observe changes in the benthic population and to create a video database of the biology of the artificial reefs.

a) Natural rocks

b) A concrete bell-shaped module

Figure 3
Installing the rocks and modules on the reef

Data analysis

To evaluate the evolution of fishery productivity after the installation of the artificial reefs, the following data were collected for each catch:

- number of specimens captured
- identification of species
- number of species (2, 19).

Table II
Sampling periods at the three artificial reef study sites

Sampling	Pescara			Torre del Cerrano			Cologna		
	2005	2006	2007	2005	2006	2007	2005	2006	2007
1	17 Jun	21 Jul	21 May	1 Sept	23 Jun	12 Jun	21 Dec	16 Jun	4 Jun
2	28 Jul	13 Sept	20 Jul	16 Sept	27 Jul	21 Jun	ND	1 Aug	27 Jun
3	18 Jan	21 Sept	4 Oct	3 Nov	5 Sept	14 Sept	ND	16 Nov	13 Jul

ND not detected

The total length, standard length, height (width) and weight were recorded for each specimen.

A comparison between the two sites in terms of biocenosis complexity degree was made using the following statistical indexes for each site:

- dominance index (15)
- specific diversity index (22)
- specific richness index (14)
- equiripartition or 'evenness' index (17)
- homogeneity or dominance index (23).

The Simpson dominance index weights towards the abundance of the most common species and therefore takes into account the number of species present, as well as the relative abundance of each species. The formula for the Simpson index is as follows:

$c = {}_{S}\Sigma_{i=1} (n_i/N)^2$

where S is the number of species, N is the total percentage cover or total number of organisms and n is the percentage cover of a species or number of organisms of a species.

The specific diversity index, ranging in theory from 0 to infinity, takes into account both number of species and distribution pattern of different species. The specific diversity index assumes that all species are represented in a sample and the sample was obtained randomly, as follows:

$H' = -\Sigma\, p_i * \ln p_i = -\Sigma\, (n_i/N) * \ln (n_i/N)$

where p_i is the proportion of individuals found in the i^{th} species, ln is the natural logarithm and N is the total number of individuals of all species.

If the environment lacks diversity, there are few widespread species and this index ranges from 0 to 1. If its value ranges from 1 to 3, there is an 'intermediate diversity' in typology and size. However, if its value is greater than 3, a 'good diversity' characterises the environment.

The specific richness index takes into account the total number of species/total number of community members ratio with the following formula:

$D = (S-1) / \log N$

where S is the number of species and N is the total number of individuals.

It quantifies the diversity relating specific richness to the total number of individuals (20) and its value increases with increasing biodiversity.

The 'evenness' index is constrained between 0 and 1.0. As with H', evenness assumes that all species are represented within the sample and quantifies how equal the communities are numerically. The formula is as follows:

$J = H'/H_{max}$

where H' is the number derived from the Shannon diversity index and H'_{max} is the maximum value of H', equal to: H'/ln S, where S is the number of species.

The lower the variation in communities between the species, the higher J will be. A maximum evenness value is observed when all the species are equally abundant.

The Simpson dominance index gives more weight to rare species than the Shannon-Weaver index and measures the prevalence of few community species with an inverse trend compared to the 'evenness' index. A high dominance suggests that one or more species monopolise resources. A low index suggests a small variety of numerous elements. It ranges between 0 and 1 and the formula is as follows:

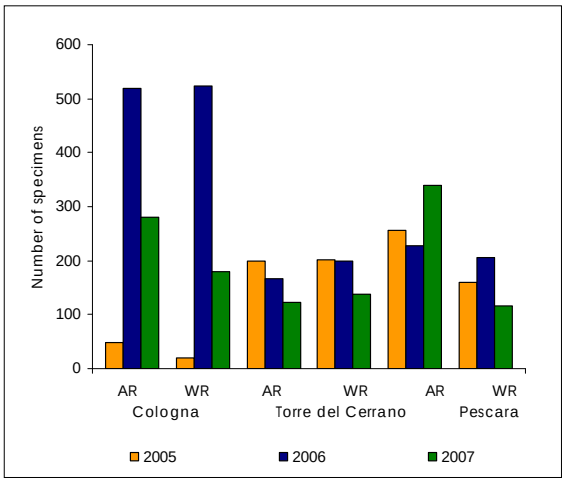
$c = \Sigma\, (n_i / N)^2$

where n_i is the total number of organisms of a particular species and N is the total number of organisms of all species.

Results

The number of specimens captured between 2005 and 2007 was always higher in the artificial reef sites in comparison to the control sites, with the exception of the Torre del Cerrano and Cologna sampling in 2006 (Fig. 4). In particular, there was a marked difference between artificial reefs and the control site in Pescara in 2007, when 339 specimens were captured from artificial reefs compared to 117 from the control site.

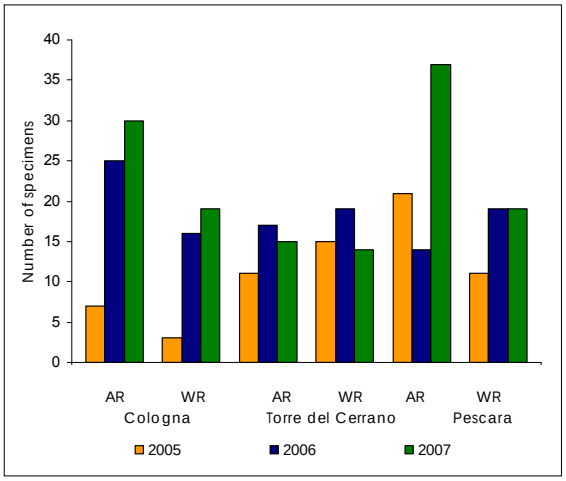
Comparing the results of monitoring conducted in 2005 with the data from 2006 and 2007, a considerable change in resources was noted, especially in regard to the number of species



AR artifical reef
WR without reef

Figure 4
Number of specimens captured in artificial reefs and in control sites (without reefs) between 2005 and 2007

captured for each sampling point. The number of species increased in the artificial reefs of Pescara and Cologna, while they remained constant in Torre del Cerrano. In regard to species captured in the control sites, an increase was observed at Cologna and Pescara, but the number of the species always remained lower than on artificial reefs (Fig. 5).

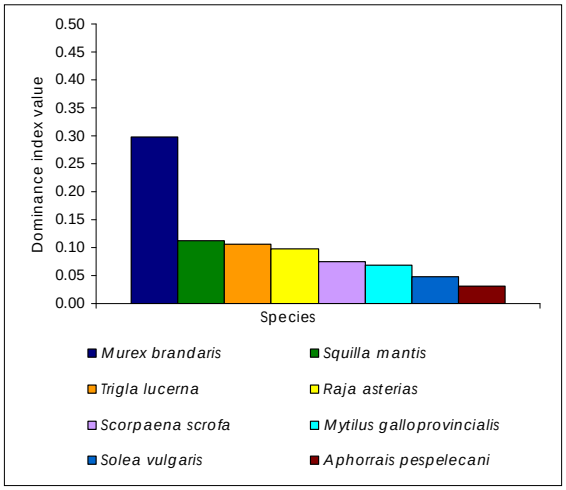


AR artifical reef
WR without reef

Figure 5
Number of species captured in artificial reefs and in control sites (without reefs) between 2005 and 2007

An analysis of the results of the dominance index (Figs 6, 7 and 8) show the prevalence of *Murex brandaris*, *Squilla mantis*, *Trigla lucerna*, *Mullus barbatus* and *Solea vulgaris* in all artificial sites of the reefs.

a) Artificial reef area



b) Control area

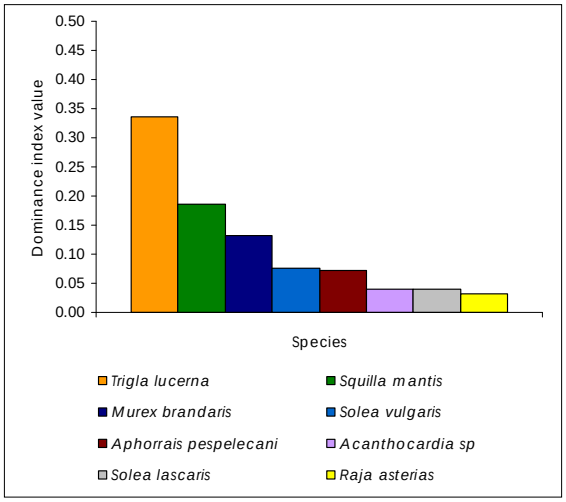


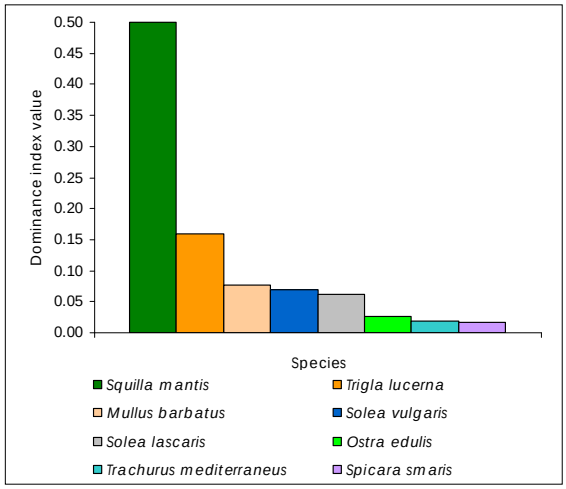
Figure 6
Cologna dominance index values for 2005, 2006 and 2007
For each site, the eight most prevalent species (total of 40 species found in artificial reefs and 25 species in control sites) were reported

An analysis of samples showed differences in the composition of species between artificial reefs and control sites. Typical hard substrate nectobenthic species were found in the artificial reef at Cologna, as follows:

- *Diplodus sargus*
- *D. annularis*

- *D. vulgaris*
- *Sciaena umbra*
- *Umbrina cirrosa*.

a) Artificial reef area



b) Control area

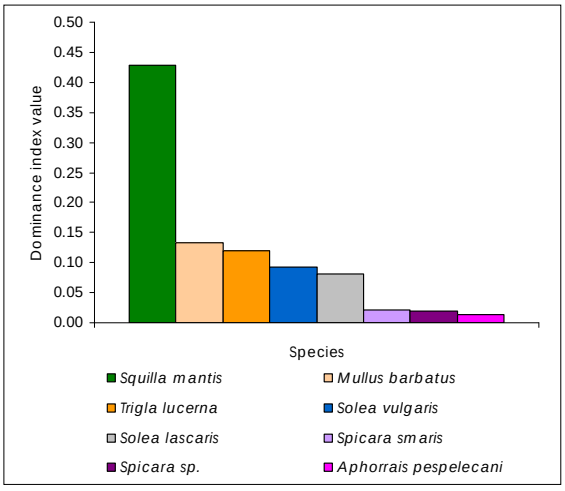
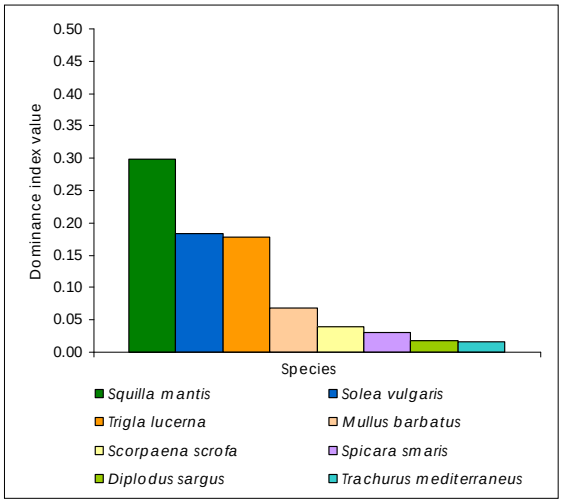


Figure 7
Torre del Cerrano dominance index values, 2005-2007
For each site, the eight most prevalent species (out of a total of 27 species found in both areas) were reported

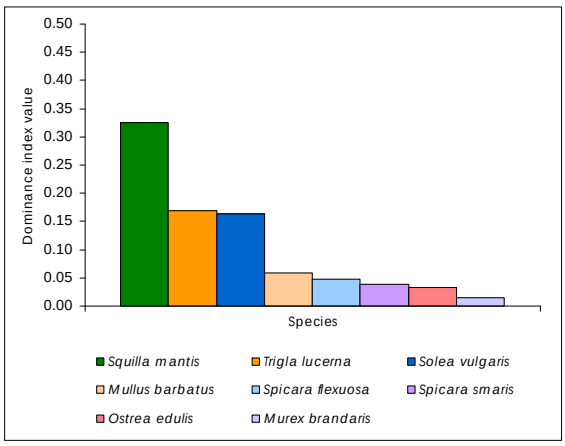
These species were observed by fishermen in Pescara.

In nearly every case, the specific diversity index value ranged from 1 to 3.15, which suggested an intermediate condition, an 'intermediate diversity' in typology and size of species, in both artificial reefs and control sites. With the exception of Torre del Cerrano, in 2005, 2006 and 2007 and Pescara in 2006,

a) Artificial reef area (centre)



b) Artificial reef area (north)



c) Control area

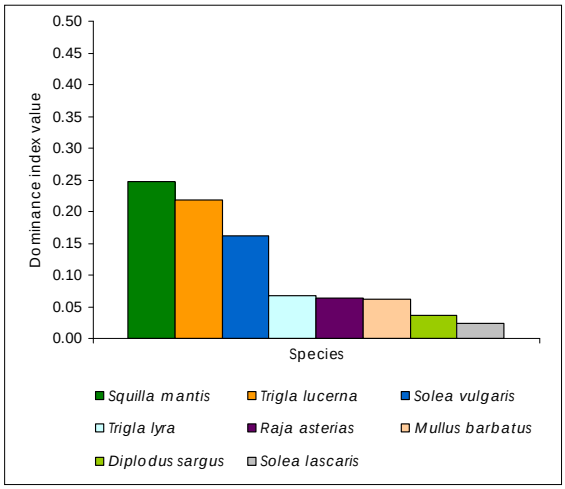
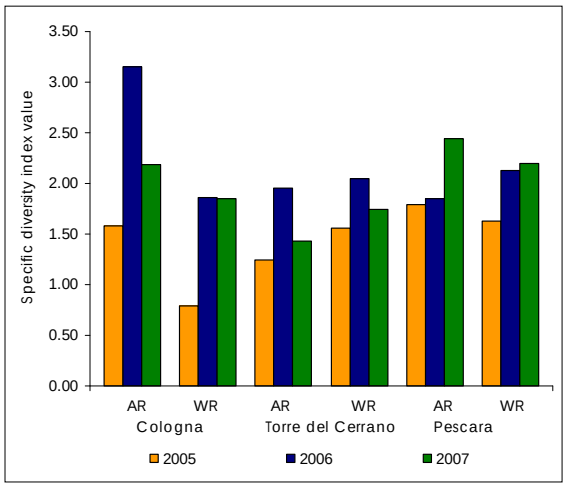


Figure 8
Pescara dominance index values, 2005-2007
For each site, the eight most prevalent species out of 27 (centre and north) and a total of 25 species (control site) were reported

specific diversity index values were higher in artificial reef sites than in the control areas (Fig. 9).



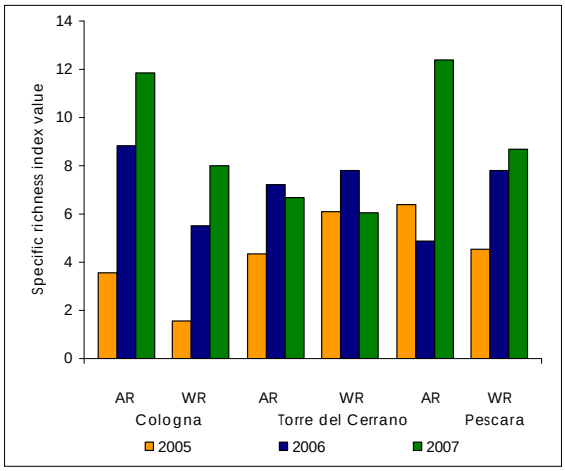
AR artifical reef
WR without reef

Figure 9
Specific diversity index values for artificial reefs and control sites (without reefs), 2005-2007

A progressively increasing trend of specific richness index values for the areas related to artificial reefs revealed greater biodiversity in the area of the sea protected by the artificial reefs. In regard to the monitoring activities conducted in Pescara, the major biodiversity and abundance of the control site compared to artificial reefs site in 2006 could have been due to the proximity between the control site and Saline River outlet, suggesting a nutrient enrichment of sea water that promoted a movement of organisms from the artificial reefs (Fig. 10). The highest increase was observed at Cologna where total richness rose from 3.55 in 2005 to 11.84 in 2007; the highest value was recorded in Pescara's artificial reef in 2007 (12.41) and the lowest increase (from 4.35 to 7.2) was observed in Torre del Cerrano from 2005 to 2006.

The 'evenness' index reaches values approaching 1, indicating that all species are equally abundant in both sites and in all locations. This index reached the maximum value for the Cologna site (0.98) (Fig. 11).

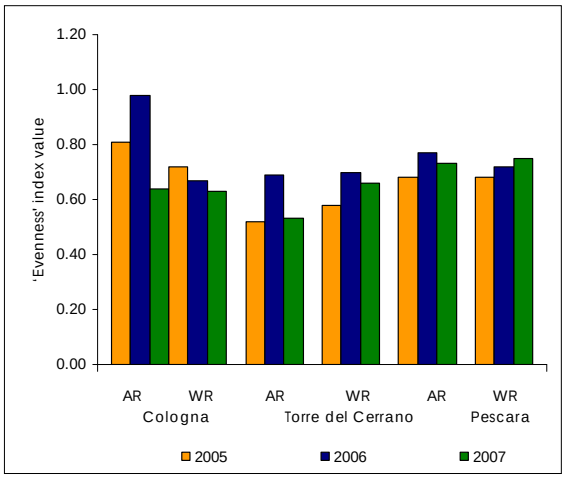
The homogeneity index ranged between 0.13 and 0.52 in all areas. These values suggest the installation of a very abundant variety of sea species. The highest value for this index was reached in 2005 in the Cologna control site (0.52) and in the artificial reef site at Torre del Cerrano in 2007 (0.45) (Fig. 12).



AR artifical reef
WR without reef

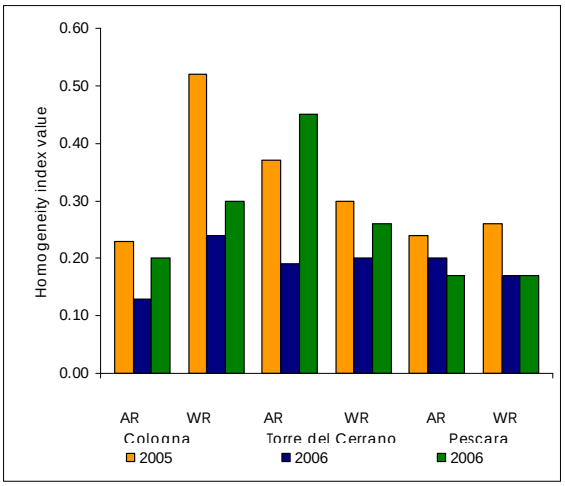
Figure 10
Specific richness index values for artificial reefs and control sites (without reefs), 2005-2007

According to the literature (13, 16, 18), annual footage shot by scuba divers showed the settlement of larval and sessile organisms on rough surfaces of artificial modules; concave holes of lateral walls were also colonised by benthic organisms and other marine species



AR artifical reef
WR without reef

Figure 11
'Evenness' index values for artificial reefs and control sites (without reefs), 2005-2007



AR artifical reef
WR without reef

Figure 12
Homogeneity index values for artificial reefs and control sites (without reefs), 2005-2007

that found refuge and a suitable habitat for survival. Footage of the three years post-deployment artificial reefs in Cologna can be viewed on the Istituto G. Caporale website (www.izs.it/IZS/Engine/RAServePG.php/P/294210010400/M/294010010300).

Conclusions

With the valuable collaboration and observations of small-scale professional fishermen, the presence of artificial reefs have greatly discouraged illegal trawling within 3 nautical miles of the coast. In conformity with other structures in European and Mediterranean artificial reefs (9, 12, 13, 16, 18, 21), the use of artificial modules has not only proved to be effective for the repopulation of ichthyic fauna and the protection of marine biodiversity, but has also increased the numbers of high commercial value marine species. The effectiveness of the artificial substrates was confirmed by the substantial increases in the quantities of halieutic resources recorded in the areas without artificial reefs, indicating a probable attraction caused by the reefs for ichthyic species in the surrounding areas.

Interestingly, the presence in Cologna's catches of *D. sargus*, *D. annularis*, *D. vulgaris*, *S. umbra* and *U. cirrosa* which were observed in captures on artificial reef sites and not in the control sites, suggests that the presence of the artificial structures may play an important role in attracting and protecting these hard substrate species.

Moreover, these results suggest that benthic hard substrate community settlements on artificial reefs may not only further increase biodiversity of the marine environment, but could potentially promote the activation of additional trophic chains with the consequent increase of ichthyic populations feeding on benthic communities (11).

In conclusion, these studies confirmed that in alternative coastline management, the potential of artificial reefs can certainly contribute to solving low-income fishery problems as well as enhancing biological diversity.

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