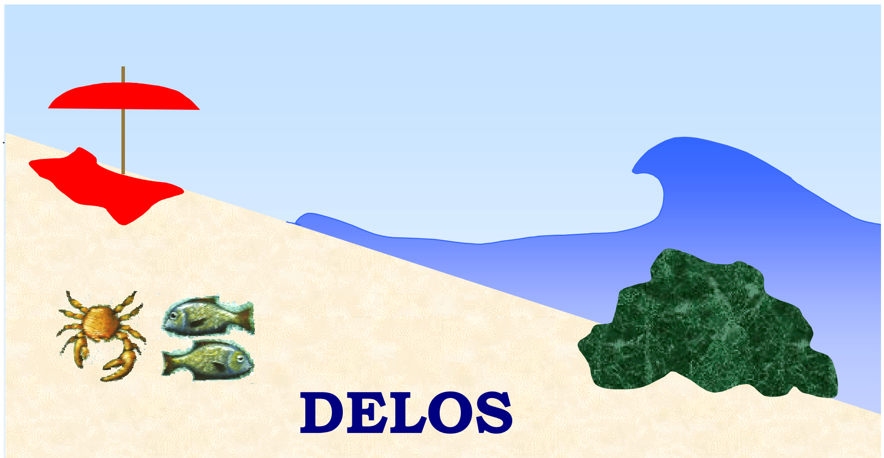
EU Fifth Framework Programme 1998-2002
Energy, Environment and Sustainable Development

Environmental Design of Low Crested Coastal Defence Structures



D39
Established contribution of breakwaters to regional biodiversity

Background and aims

Fig. 1. Coastal defence structures along the Italian coasts of the north Adriatic sea

Artificial structures are a common and increasing feature of many urbanised sandy coastal areas (Glasby & Connell 1999, Chapman & Bulleri 2003). Despite the resulting increase of rocky habitats, which in some areas can affect over half of the natural shoreline, little is known about how marine organisms respond to the addition of artificial structures (Davis et al. 2002, Bacchiocchi & Airoldi 2003).

The overall aim of WP 3.4. is to assess large-scale effects of breakwater spatial arrangement (i.e. location, relative proximity to natural reefs and other artificial structures) on the distribution and population dynamics of species of hard bottom substrata. As a first step to achieve this goal, the composition and structure of assemblages associated to artificial reefs along the Italian shores of the North Adriatic Sea were analysed. In this area natural rocky reefs are rare, and over 60 % of the coastline is characterized by the presence of hard structures for defence and stabilization of shores (Fig. 1 and Fig. 2A). In the previous deliverable D.29 the relationships between the location of breakwaters and the abundance of epibiota over large spatial scales were identified. In particular, an overall pattern of increasing species richness was found from North to South. The present deliverable D.40 aims at identifying the effects of artificial structures on the regional distribution and diversity of hard bottom assemblages. In order to evaluate these effects (1) the composition and structure of assemblages associated to artificial reefs were compared to that of assemblages associated to nearby natural rocky reefs where occurring, and (2) the contribution of artificial reefs in terms of introduction of hard bottom species was evaluated in areas where no rocky reefs occur naturally.

Methods

The composition and abundance of intertidal and subtidal assemblages on defence structures and natural reefs were analysed in May 2000 along about 400 km of coasts (Fig 2B). Sampling covered 3 scales: (1) 10s to 100s kms (distance among locations), (2) 10s to 100s ms (distance among areas within locations) and (3) 1 to 10s ms (distance

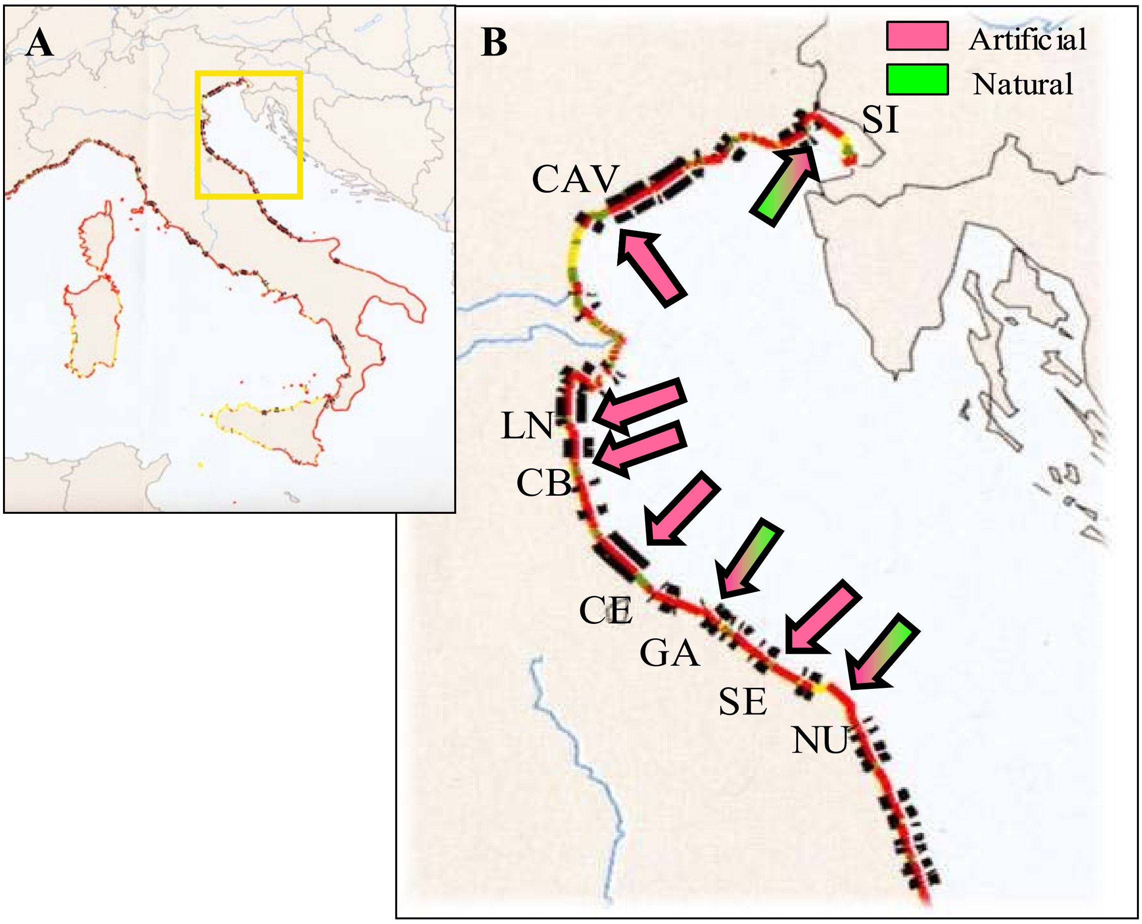


Fig. 2. (A) Map of the study area, with indications of coasts threatened by erosion (red line) and coasts protected by defence structures (black bars) and (B) location of the sampling stations, with indication of the 3 natural reefs occurring in the area

among plots within areas). At 3 locations (SI, GA and NU, see Fig. 2B) sampling of intertidal and subtidal assemblages was done on both natural reefs and artificial structures, while at the remaining 5 locations only intertidal assemblages on artificial structures were sampled because of lack of natural reefs (Fig. 2B) and because of high turbidity, that prevented visual sampling in the subtidal. At each location, 4 areas on defence structures (either breakwaters or groins) and, if occurring, on natural reefs were sampled. As natural reefs were exposed promontories with little or no shelter, defence structures were sampled on their exposed sides, in order to obtain comparable conditions of wave exposure between artificial and natural habitats. Ten replicate plots of 20 x 20 cm were sampled in each area, by using a visual method (Benedetti-Cecchi et al., 1996).

Results and discussion

Table 1. Intertidal specie recorded on costal defence structure and natural rocky reefs at SI, GA and NU. C=coastal defence structures, N= natural reef. Presence or absence of species is indicated as + and –, respectively.

Taxa	**SI**		**GA**		**NU**	
	N	**C**	**N**	**C**	**N**	**C**
Microfilm (microalgae, spores, germlings)	-	-	-	+	-	+
Rhodophycota						
Aglaothamnion caudatum (J. Agardh) Feldmann - Mazoyer	-	-	-	+	-	-
Antithamnion cruciatum (C. Agardh) Nägeli	-	-	+	+	+	+
Catenella caespitosa (Withering) L.M. Irvine	+	-	-	-	-	-
Ceramium ciliatum (J. Ellis) Ducluzeau	-	-	+	-	-	-
Ceramium diaphanum (Lightfoot) Roth	-	-	-	-	+	+
Ceramium rubrum (Hudson) C. Agardth	-	-	-	+	+	+
Chondracanthus acicularis (Roth) Fredericq	-	-	-	-	+	-
Corallina elongata J. Ellis et Solander	-	-	-	-	+	+
Encrusting corallines	-	-	+	+	+	+
Gastroclonium clavatum (Roth) Ardissone	-	-	+	-	+	-
Gelidium spinosum (S.G. Gmelin) P.C. Silva	-	-	-	+	+	+
Hildenbrandia rubra (Sommerfelt) Meneghini	-	-	-	-	+	-
Laurencia juv.	-	-	-	-	+	-
Lomentaria clavellosa (Turner) Gaillon	-	-	+	-	+	-
Nemalion helminthoides (Velley) Batters	-	-	-	-	+	-
Osmundea ramosissima (Oeder) Athanasiadis	-	-	+	-	+	-
Polysiphonia opaca (C. Agardh) Moris & De Notaris	-	-	+	-	+	+
Polysiphonia subulata (Ducluzeau) J. Agardh	+	-	-	+	-	-
Porphyra sp. 1	+	-	-	-	-	-
Pterocladiella melanoidea (Schousboe ex Bornet) Santelices et Hommersand	+	-	-	-	-	-
Chlorophycota						
Bryopsis corymbosa J. Agardh	-	-	-	-	+	+
Bryopsis hypnoides J.V. Lamouroux	-	-	-	+	-	-
Bryopsis plumosa (Hudson) C. Agardh	-	-	+	-	+	+
Chaetomorpha linum (O. F. Müller) Kützing	-	-	-	-	+	+
Enteromorpha intestinalis (Linnaeus) Nees	+	+	+	-	+	-
Pedobesia lamourouxii (J. Agardh) Feldmann, Loreau, Codomier & Couté	-	-	-	-	+	-
Ulva curvata (Kützing) De Toni	-	-	-	+	-	-
Ulva laetevirens Areschoung	+	+	+	+	+	+
Phaeophycota						
Ectocarpacee unidentified	+	+	+	-	-	-
Cladostephus spongiosus (Hudson) C. Agardh	-	-	-	-	+	-
Cystoseira barbata (Stackhouse) C. Agardh	-	-	-	-	+	-
Dictyota dichotoma var. *intricata* (C. Agardh) Greville	-	-	+	+	+	+
Ralfsia verrucosa (Areschoug) Areschoug	-	-	+	-	+	+
Scytosiphon lomentaria (Lyngbye) Link	+	+	-	-	-	-
Porifera						
Cliona spp.	-	-	-	-	+	+
Anthozoa						
Actinia equina (Linnaeus)	-	-	-	-	-	+
Bivalvia						
Mytilus galloprovincialis (Lamarck)	+	+	+	+	+	+
Ostrea spp.	-	-	-	+	-	-
Gastropoda						
Osilinus turbinatus (Von Born)	+	+	+	-	+	+
Patella spp.	+	+	+	+	+	+
Crustacea						
Balanus spp.	+	+	-	+	+	+
Chthamalus spp.	+	+	+	+	+	+
Bryozoa						
Encrusting bryozoa	+	-	-	-	-	-

Results for intertidal assemblages are reported. The composition and structure of intertidal assemblages associated to artificial structures and nearby natural rocky reefs at SI, GA and NU is shown in Table 1. A trend of increasing species richness from North to South was observed. This pattern is consistent with results presented in Deliverable D.29. At all locations assemblages were characterized by the presence of *Mytilus galloprovincialis*, *Ulva laetevirens*, *Chtamalus* spp. and *Patella* spp. that were abundant on both artificial and natural reefs. Conversely, several species of algae, including *Corallina elongata*, *Cystoseira barbata* and numerous species of filamentous algae belonging to the taxum Rhodophycota, were only found at NU. Overall, the total number of species detected in each habitat was higher on natural reefs than on artificial structures.

Multivariate analyses showed significant differences in the composition and abundance of species between intertidal assemblages on defense structures and natural reefs at SI, GA and NU. This result is synthesized by the Principal Coordinate Analysis (Fig. 3): despite the marked differences among locations, this analysis showed how assemblages colonizing artificial structures grouped distinctively from those colonizing natural reefs at all stations. Differences between natural and artificial reefs were less evident at the level of individual species (e.g. Fig. 4). In most cases, in fact, differences

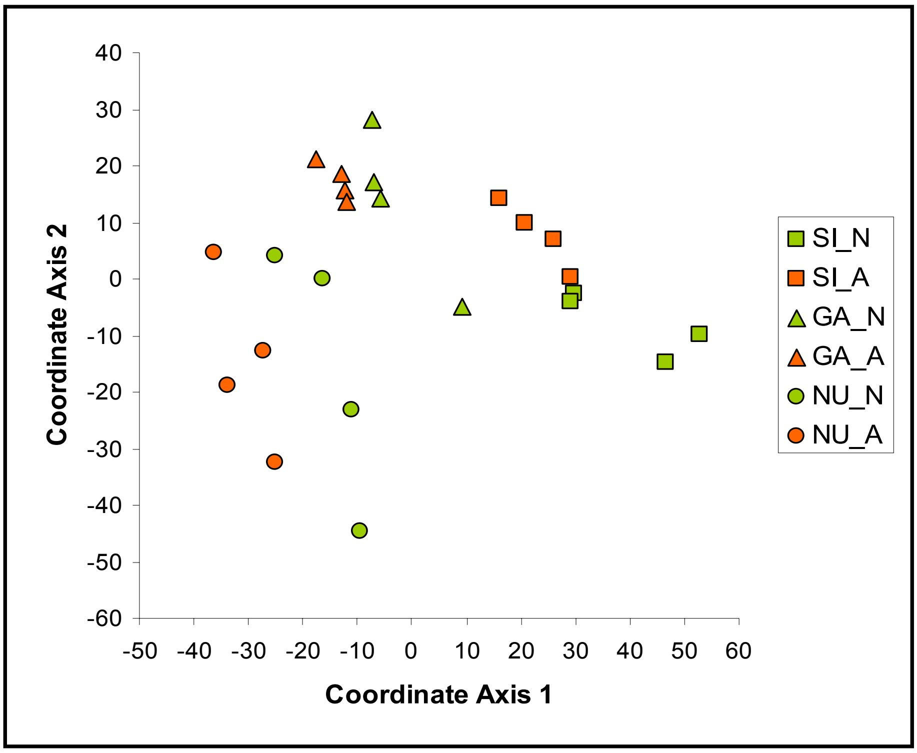


Fig. 3. Principal coordinate analysis of assemblages on natural reefs (_N) and artificial structures (_A) at SI, GA and NU.

between natural reefs and artificial structures were not consistent among locations, resulting in significant interactions between the factors habitat and location (e.g. Table 2).

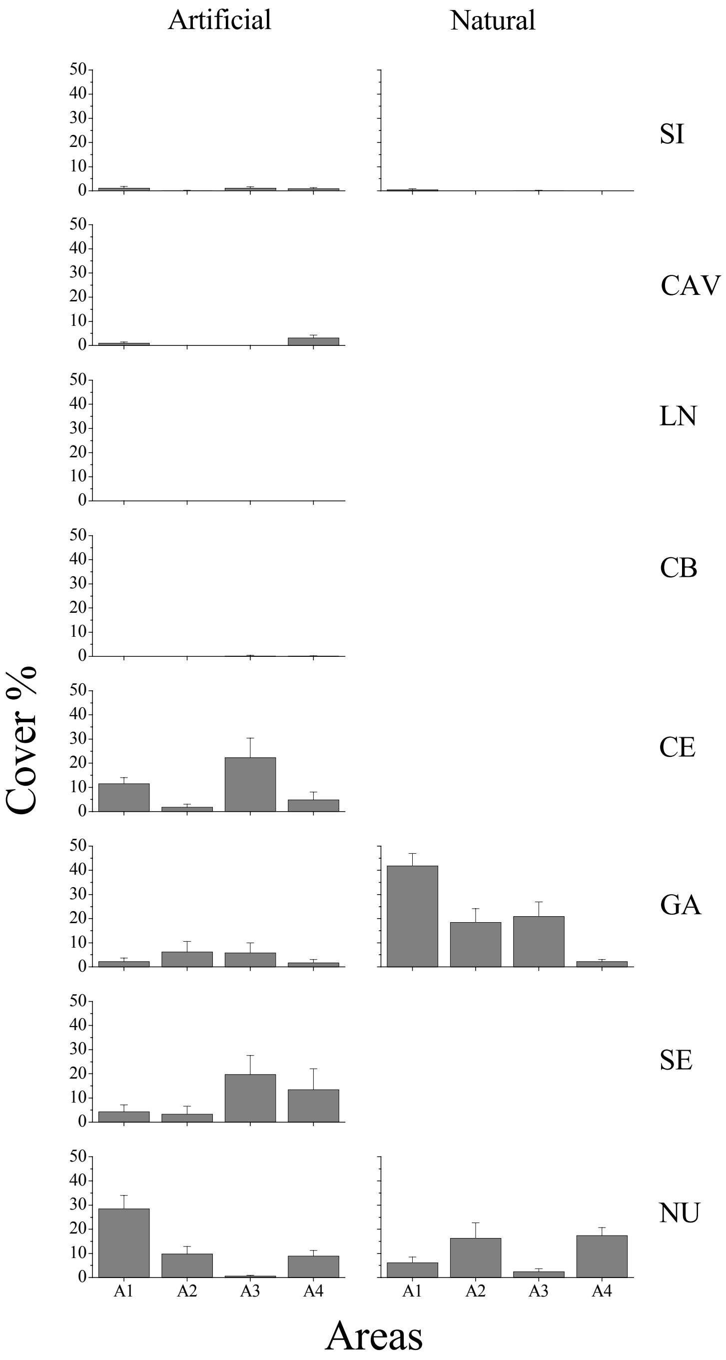


Figure 4. Distribution of filamentous algae on artificial structures and natural reefs (where occurring) at the study sites in the North Adriatic Sea

Table 2. ANOVA of covers of filamentous algae on coastal defence structures and natural rocky reefs. Factors are: Location (3 locations, random), Habitat (natural = nat, artificial = art, fixed) and Area (4 areas, random, nested in Location x Habitat). ns = not-significant, * p < 0.05, ** = p< 0.01, *** = p<0.001. SNK test was used for *a posteriori* multiple comparison of means.

Source of variation	d.f.	MS	*F*		SNK test		
Location = Lo	2	5019	7,72	**			
Habitat = H	1	1133	0,48	ns			
L x H	2	2378	3,66	*	SI: nat = art	GA: nat > art	NU: nat = art
Area (Lo x H)	18	650	7,64	***			
Residual	216	85					

In areas where no natural hard substrata occurred, assemblages on defence structures were generally characterised by low species richness and spatial dominance by species with a large dispersal range, such as *Mytilus galloprovincialis* and green ephemeral algae (see also Bacchiocchi & Airoldi 2003). These species are also abundant in the coastal lagoons of the region as well as on other types of artificial coastal structures (Ceccherelli & Rossi, 1984, Relini *et al*., 1998). This is relevant to the management of defence structures and other types of artificial structures (Bacchiocchi & Airoldi 2003). Human-made structures are, in fact, considered a benefit to coastal sandy areas of the Adriatic sea for their potential to increase local species diversity by allowing the settlement of new species that usually live on rocky reefs (Bombace *et al*., 1995). Present results, however, suggest that artificial structures may act by changing the patterns of distribution of locally abundant species rather than by increasing species diversity. Similar hypotheses have been suggested by Glasby (1999) and Glasby & Connell (1999), who raised concern that human-made structures may cause considerable change to the identity and/or abundance of epibiotic species within an area, but that in most cases the possible consequences of these changes to coastal assemblages are not taken into account. In areas where no natural hard substrata occur, such as the coasts of Emilia Romagna, effects due to the extensive presence of artificial structures can be particularly relevant. For example, while growth of mussels on artificial structures is perceived as a benefit (Relini *et al*., 1998), the flowering of ephemeral green algae that are torn off the structures and washed up the shore is a major problem for beach tourism.

Conclusions

1) Although defence structures were colonised by rocky-bottom species, their assemblages differed from those occurring on nearby natural reefs. The possible causes of such differences are under investigation.

2) The massive introduction of defence structures during the last 30 years along the North Adriatic coasts has dramatically changed the coastal landscape and has affected the abundance and distribution of some species within this region. Work is in progress to understand the ecological consequences of these changes.

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