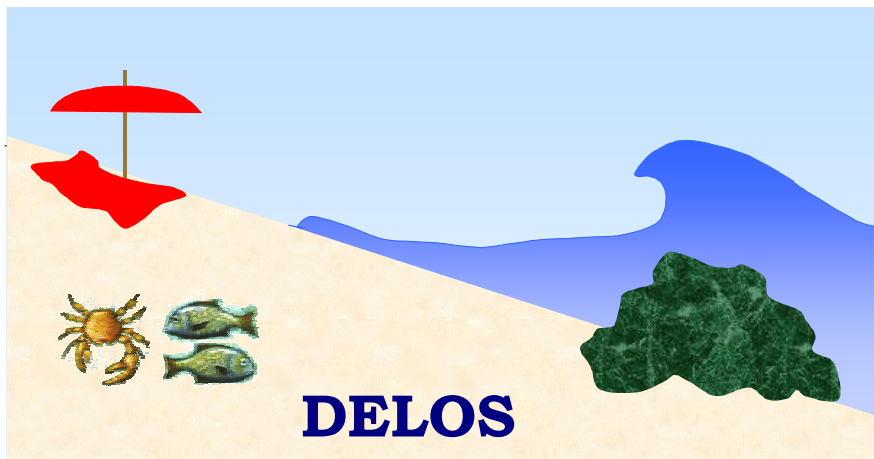


**EU Fifth Framework Programme 1998-2002
Energy, Environment and Sustainable Development**

Environmental Design of Low Crested Coastal Defence Structures



D29

**Relationships between breakwater spatial
arrangement and large-scale species
distribution**

Background and aim

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. The first step to attain this goal was to identify whether there are any

Table 1. Most abundant species of algae and invertebrates found in intertidal habitats on coastal defence works along the North Adriatic coasts

ALGAE
<i>Antithamnion cruciatum</i> (C. Agardh) Nägeli
<i>Bryopsis corymbosa</i> J. Agardh
<i>Bryopsis hypnoides</i> Lamouroux
<i>Bryopsis plumosa</i> (Hudson) C. Agardh
Ceramiacea unidentified
<i>Ceramium ciliatum</i> (J. Ellis) Ducluzeau
<i>Ceramium diaphanum</i> (Lightfoot) Roth
<i>Ceramium rubrum</i> (Hudson) C. Agardh
<i>Chaetomorpha linum</i> (O. F. Müller) Kützing
<i>Chaetomorpha mediterranea</i> (Kützing) Kützing
<i>Cladophora echinus</i> (Biasoletto) Kützing
<i>Codium fragile</i> (Suringar) Hariot
<i>Corallina elongata</i> , J. Ellis & Solander.
<i>Corallina officinalis</i> Linnaeus
<i>Dictyota dichotoma</i> (Hudson) Lamouroux
Ectocarpaceae unidentified
Encrusting corallines
<i>Enteromorpha intestinalis</i> (Linnaeus) Nees
<i>Fauchea repens</i> (C. Agardh) Montagne & Bory
<i>Gelidium spinosum</i> (S. G. Gmelin) P. C. Silva
microfilm (microalgae, spores, germlings)
<i>Petalonia fascia</i> (O. F. Müller) Kuntze
<i>Polysiphonia opaca</i> (C. Agardh) Moris & De Notaris
<i>Polysiphonia</i> sp.1
<i>Polysiphonia</i> sp.2
<i>Polysiphonia subulata</i> (Ducluzeau) P. & H. Crouan
<i>Porphyra</i> spp.
<i>Ralfsia verrucosa</i> (Areschoug) Areschoug
<i>Scytosiphon lomentaria</i> (Lyngbye) Link
<i>Ulva laetevirens</i> Areschoug
INVERTEBRATES
<i>Actinia equina</i> (Linnaeus, 1758)
<i>Balanus perforatus</i> Bruguière, 1798
<i>Chthamalus stellatus</i> (Poli, 1791)
<i>Cliona</i> spp.
<i>Crassostrea gigas</i> (Thunberg, 1793)
<i>Euraphia depressa</i> (Poli, 1791)
<i>Mytilus galloprovincialis</i> Lamarck, 1819
<i>Osilinus turbinatus</i> (von Born, 1778)
<i>Ostrea edulis</i> Linnaeus, 1758
<i>Patella caerulea</i> , Linnaeus, 1758
<i>Patella rustica</i> , Linnaeus, 1758
Polyplacophora unidentified
Serpulidae unidentified

relationships between the location of breakwaters and the abundance of epibiota over large spatial scales. In the following report, we present results from the sampling program which was specifically designed to identify such relationships. The study covered about 400 km of the Italian shores of the North Adriatic Sea, which is characterized by the presence of extensive defence schemes. The aims of the study were: (1) to characterise the composition and structure of intertidal assemblages associated with coastal defence works and (2) to identify the major discontinuities in the distribution of dominant species. The scales covered by the study ranged from (1) 10s to 100s km (distance among locations), (2) 10s to 100s of m (distance among breakwaters within locations) and (3) 1 to 10s of m (distance among plots within breakwaters).

Results

A total of 30 species of algae and 13 species of invertebrates were found in intertidal assemblages associated with coastal defence works along the coasts of the North Adriatic Sea (Table 1). Mussels and ephemeral macroalgae were by far the quantitatively dominant species at most locations. *Mytilus galloprovincialis* was found at each location, sometimes with average cover values up to 90% (Fig. 1, note that locations are ranked from North to South). The most abundant ephemeral macroalgae were the green algae *Enteromorpha*

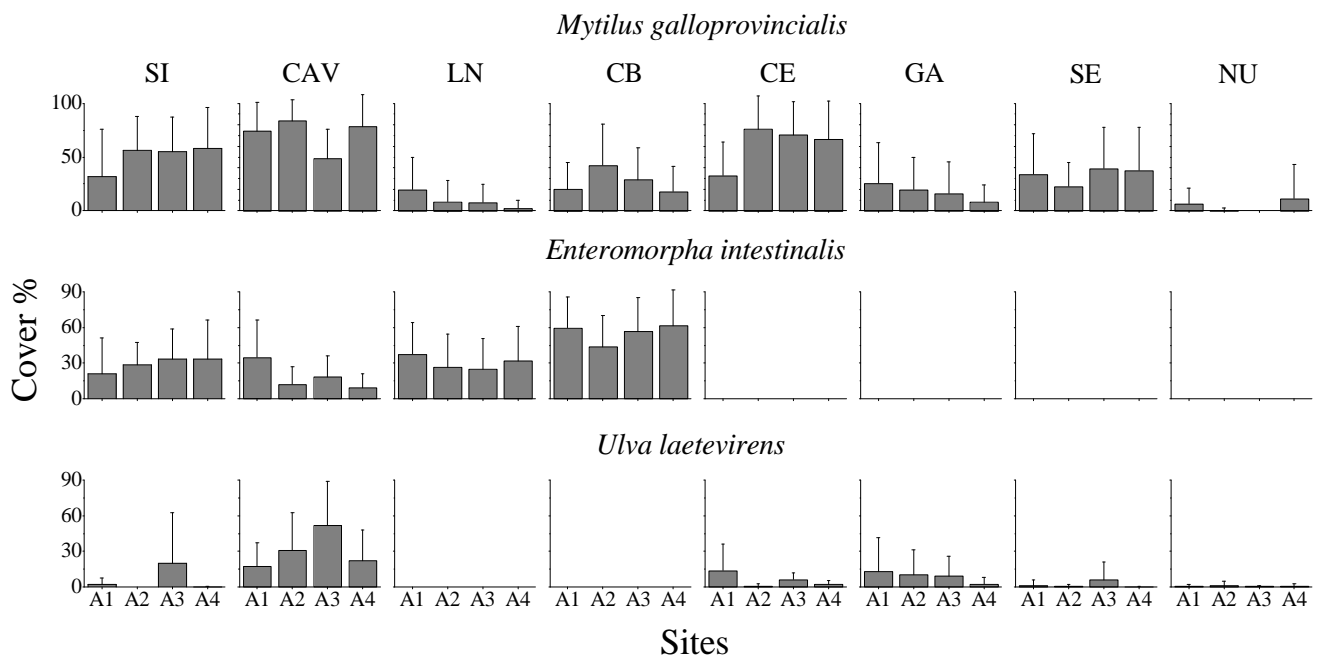


Figure 1. Distribution of *Mytilus galloprovincialis*, *Enteromorpha intestinalis* and *Ulva laetevirens* in intertidal habitats on coastal defence works in the North Adriatic Sea. Data are mean percent covers (+ 1 SD, n = 10) measured at 4 breakwaters (A1, A2, A3 and A4) at each of 8 locations.

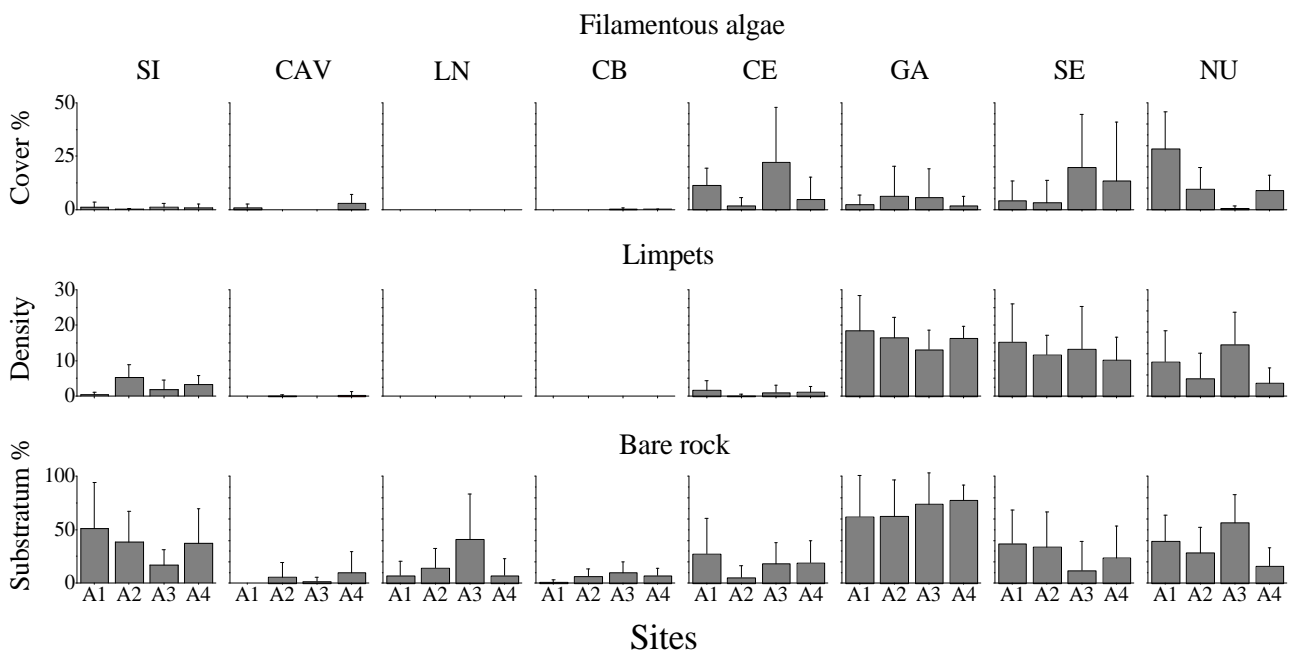


Figure 2. Distribution of filamentous algae (including green, red and brown algae), limpets and bare rock (i.e. rock not covered by any macroscopic visible organisms) in intertidal habitats on coastal defence works in the North Adriatic Sea. Data are mean percent covers (+ 1 SD, n = 10) measured at 4 breakwaters (A1, A2, A3 and A4) at each of 8 locations.

intestinalis (Fig. 1) and *Ulva laetevirens* (Fig. 1). Filamentous species were also very abundant (Fig. 2), mainly including red algae belonging to the order Ceramiales, but also several species of green and brown algae. Species of algae with a more persistent life-cycle, such as *Corallina* spp. and *Dictyota dichotoma*, were found almost exclusively at the southern location. Encrusting corallines and other crustose algae were generally rare.

Among the invertebrates, oysters were the most abundant sessile species following mussels. *Chthamalus stellatus* was also present, but this species tended to dominate at higher levels on the shore. Limpets (mainly *Patella caerulea*) were the most abundant mobile species, although their densities largely differed among locations (Fig. 2).

The distribution of species was heterogeneous at all scales investigated. At the scale of meters the assemblage was patchy, as shown by the large standard deviations (Figs. 1 and 2). Patches of mussels alternated with patches of green ephemeral and filamentous algae and with patches of rock not covered by any macroscopic visible organisms or covered by a thin microfilm of microalgae, spores and germlings of macroalgae. The microfilm and ephemeral green algae also frequently occurred on mussels, however they were generally more abundant on primary substrata. Similarly, limpets were abundant in patches of bare rock, while they were rarely found within algae and almost never within mussels.

Abundance of dominant species also varied among nearby breakwaters within each location. Differences, although generally significant (Table 2), were quantitatively

Table 2. ANOVAs of percent covers of dominant species of plants and bare rock, density of limpets and number of species associated to breakwaters along the North Adriatic coasts. ns = non-significant, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

Source of variation	d.f.	M.S.	F
<i>Filamentous algae</i>			
Location = Lo	7	1597.42	4.3**
Site (Lo)	24	371.29	4.29***
Residual	288	86.54	
<i>Enteromorpha intestinalis</i>			
Location = Lo	7	16873.1	52.55***
Sites (Lo)	24	321.08	0.96ns
Residual	288	333.29	
<i>Ulva laetevirens</i>			
Location = Lo	7	3774.20	10.79***
Sites (Lo)	24	349.83	2.06**
Residual	288	169.95	
<i>Mytilus galloprovincialis</i>			
Location = Lo	7	23924.4	17.6***
Site (Lo)	24	1359.5	1.6**
Residual	288	848.45	
<i>Patella</i> spp.			
Location = Lo	7	47.1	42.92***
Site (Lo)	24	1.09	2.73***
Residual	288	0.4	
Bare rock			
Location = Lo	7	176.31	12.55***
Site (Lo)	24	14.04	2.21**
Residual	288	6.34	
Number of species			
Location = Lo	7	2.1	9.76***
Site (Lo)	24	0.21	1.8*
Residual	288	0.11	

smaller than those observed among nearby patches within each breakwater (Figs. 1 and 2). Among the dominant species, filamentous algae were those which showed the major discontinuities in their abundance among nearby breakwaters (Fig. 2). Conversely, *Enteromorpha intestinalis* was the most homogeneous species among breakwaters within each location (Fig. 1).

The greatest differences in the distribution of species were found at large spatial scales among locations (Table 2). Overall, there was a trend of decreasing abundance of *Mytilus galloprovincialis* and ephemeral green algae from northern to southern locations (Fig. 1). This appeared to be paralleled by an increase in the abundance of bare rock, limpets, filamentous algae and many other species of algae and animals that were only found at southern locations (Fig. 2). This resulted in a general pattern of increasing species richness from North to South (Fig. 3, Table 2).

The relationship between the location of breakwaters and the large-scale distribution of species is illustrated in Figure 4. The graph shows marked differences in the composition and abundance of species among breakwaters at different locations, with the greatest discontinuities occurring among assemblages associated to structures located north and south of Cesenatico.

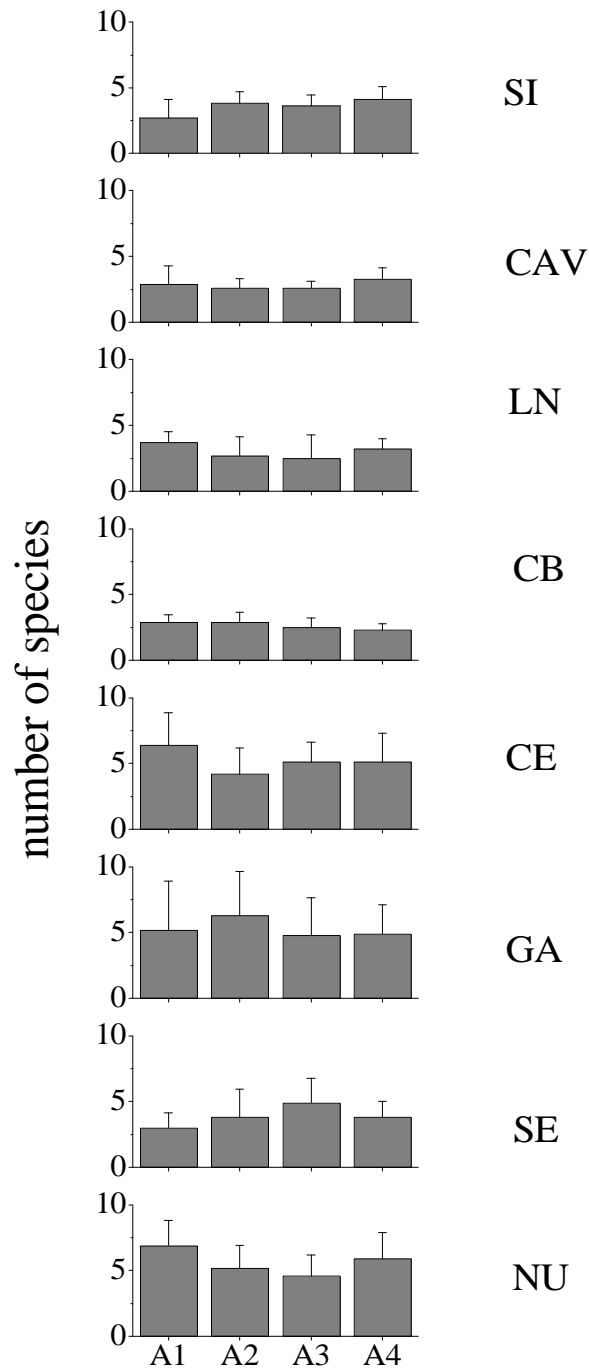


Figure 3. Number of species of plants and animals found in intertidal habitats on coastal defence works in the North Adriatic Sea. Data are mean number of species (+ 1 SD, n = 10) found at 4 breakwaters (A1, A2, A3 and A4) at each of 8 locations.

Conclusions

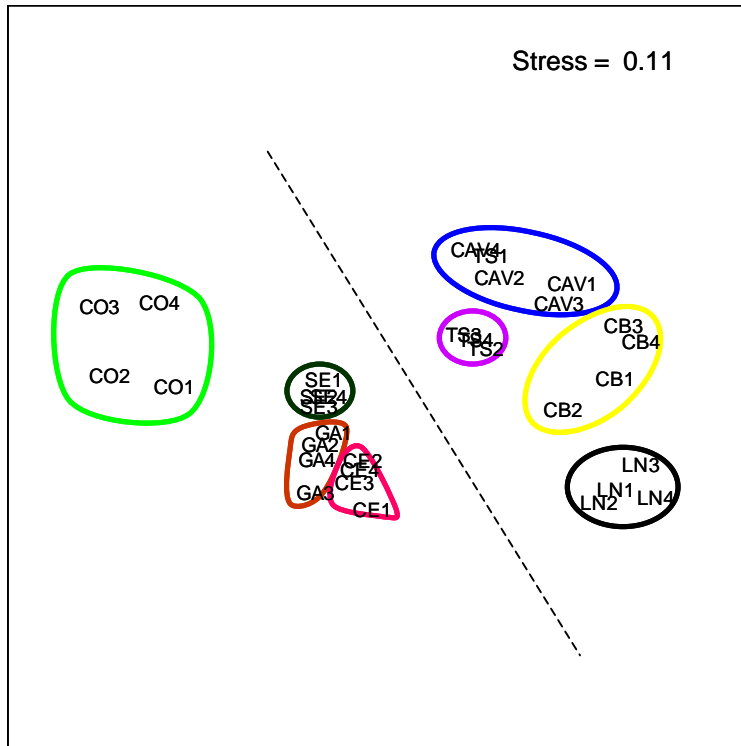


Figure 4. n-MDS plot showing relationships between the location of breakwaters and the distribution of epibiota along the coasts of the North Adriatic sea.

Major differences in the composition and abundance of intertidal species were observed at large spatial scales in relation to the location of breakwaters. Species had a variable distribution among locations, resulting in an overall pattern of increasing species richness from North to South. A trend of decreasing abundance of mussels and *E. intestinalis* was paralleled by a trend of increasing abundance of limpets, filamentous algae, bare rock and a variety of rarer species. This suggests that large-scale patterns of distribution of species on defence works in the North Adriatic Sea are probably the result of complex interactions between climate, environmental factors and the adaptive, competitive and reproductive characteristics of the important space occupiers. Interestingly, locations with less diverse assemblages of plants and animals were those located in the provinces of Ferrara and Ravenna: these locations were not only the closest to the Po river delta but also the farthest from any natural rocky reefs. This suggests that the observed large-scale patterns could be possibly influenced either by geographical gradients of salinity and other physical/chemical characteristics of the water masses related to the Po river plume, and/or by patterns of species dispersal from natural to artificial structures.

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