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# Rocky macrozoobenthos mediolittoral community in the Gulf of Trieste (North Adriatic) along a gradient of hydromorphological modifications

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*Despite the increasing urban and industrial development in coastal areas our knowledge on direct consequences of coastal modifications on benthic communities is still limited. The aim of the present study was to assess the response of rocky macrozoobenthos mediolittoral communities to human-induced hydromorphological pressures. Sampling was carried out by SCUBA diving and snorkeling in June 2008. Ten sites were selected along a gradient of hydromorphological alterations in the southern part of the Gulf of Trieste. Variables used to describe the stressor gradient were: water retention (from normal hydrology in unprotected coast to closed areas with only one opening), substrate composition, texture and rugosity. Despite natural differences between upper and lower mediolittoral subbelts, the present work showed that human-induced alterations of the coastal zone impact biological assemblages. There was a marked difference in biodiversity among sites with pristine conditions and stressed zones, mainly due to evenness of species distribution. Structural complexity of the substrate resulted to be the main factor influencing benthic diversity in the upper mediolittoral subbelt, while in the lower subbelt also the human-induced water retention seemed to play a key role. Anyhow, this response was complex, and the major human-induced alterations considered had different level of pressure within the two subbelts. The current study has a good potential to contribute to existing coastal assessment methods, since the impact of hydromorphological pressures on mediolittoral communities was almost neglected in the past. However, further work is needed to fully explain the impact of main human-induced threats on benthic communities.*

**Key words:** Zoobenthos, Artificial substrata, Intertidal environment,
Hydromorphological modifications, Ecological distribution, Gulf of Trieste

## INTRODUCTION

Despite the century-old tradition in oceanographic research in the Gulf of Trieste, knowledge on macrozoobenthic communities is still far from being satisfactory. In that regard, hard bottom macrozoobenthos deserved much less attention than soft bottom communities, with a lower number of published works (for example VATOVA, 1943; HUVÉ *et al*., 1963; SPECCHI, 1966; GAMULIN-BRIDA, 1967; OREL & SPECCHI, 1967; ZAVODNIK, 1967; SPECCHI & OREL, 1969; OREL, 1988; 1991; BETTOSO *et al*., 1999; PANNACIULLI & RELINI, 2000; BACCHIOCCHI & AIROLDI, 2003; LIPEJ *et al.,* 2006).Sampling on hard bottoms was always difficult, since it cannot be performed through standard methods traditionally used for soft bottoms, such as grabs (VATOVA, 1943; DELLA

CROCE, 1997), and it usually requires underwater sampling using scrapers or sorbonas. Only with the improvement of SCUBA diving techniques a more extensive and accurate sampling of these communities became possible (DELLA CROCE, 1997; BETTOSO *et al.*, 1999; PANNACCIULLI & RELINI, 2000; BACCHIOCCHI & AIROLDI, 2003; RINDI & BATTELLI, 2005).

Despite the still increasing human concentration in coastal areas, direct consequences of high urban and industrial development with related coastal modifications on coastal benthic communities have not been sufficiently elucidated (BENEDETTI-CECCHI *et al.*, 2001; CHAPMAN & BULLERI, 2003; BACCHIOCCHI & AIROLDI, 2003). Attention was recently paid to communities growing on artificial substrate, with the aim to prevent damages to human-made structures (RELINI, 1974; CORNELIO & OCCHIPINTI AMBROGI, 2001; RELINI, 2003). Moreover, little is known about types of assemblages growing on defense structures (REISH, 1984; LEEWIS *et al.,* 1989; COLLINS *et al.*, 1994; BULLERI *et al.*, 2000) and their distribution, (BACCHIOCCHI & AIROLDI, 2003). Little is known also about the response of assemblages to local modification of water circulation, due to hard coastal-defense structures, such as breakwaters (UNDERWOOD, 1981; HAWKINS, 1983; MENGE *et al.*, 1993; DENNY, 1995; DAVIS *et al.*, 2002).

Interest on these topics is currently increasing, as the study of benthic communities showed to be a useful tool for the evaluation of seawater quality and for environmental impact assessment. Due to organisms' tight relations with the sea-bottom and their relatively long life cycles, these communities provide a more complete and long-term information on global system' state than mere physical-chemical parameters analysis (PEARSON & ROSEMBERG, 1978; MAGNI *et al.*, 2005; SALAS *et al.*, 2006; VAN HOEY *et al.*, 2010). For this reason, benthic invertebrates are one of biological elements used to determine the Ecological Status (ES) of coastal waters, according to the European Water Framework Directive (WFD - Directive 2000/60/EC). This Directive requires that Member States protect, enhance and restore all surface Water Bodies (WBs) - with some exception regarding artificial and heavily modified WBs - with the aim of achieving *Good* ES of surface waters by 2015. Consequently, they have to also establish related monitoring programs.

The aim of the present study is to improve the knowledge about the distribution of macrozoobenthic communities on mediolittoral rocky substrates, which are the most directly affected by the rapid widespread of human-induced coastal modifications. In particular, the study was aimed at clarify the response of these communities to hydromorphological pressures in the North Adriatic area.

## MATERIAL AND METHODS

### Study area

The Gulf of Trieste is the northernmost part of both the Adriatic and the Mediterranean sea. It extends from Savudrija Cape (Croatia) to Grado (Italy) and includes the entire Slovenian coast.

The area is characterized by the biggest tidal differences and the lowest winter temperatures in the Mediterranean Sea. Amplitude of principal lunar semidiurnal constituent approaches 30 cm and temperature can go below 10°C in winter (BOICOURT *et al.*, 1999). Salinity is about 37 psu on average, but it is influenced, particularly near the coast, by fresh water input from rivers - mainly from Isonzo River (MOZETIČ *et al.*, 1998). During summer, a typical thermal stratification of the water column develops, due to surface heating and fresh water inflow (BOICOURT *et al.*, 1999). In winter the water column is characterized by considerable vertical homogeneity, due to autumnal cooling and wind mixing (MOZETIČ *et al.*, 1998). Because of its shallowness, the Gulf responds to local atmospheric forcing (i.e. dominant winds) (MOZETIČ *et al.*, 1998).

The hydrodynamic of the Gulf of Trieste is linked mainly to the ascending eastern current coming from the Istrian coast (STRAVISI, 1983). The general circulation pattern is predominantly counter clockwise in the lower layer and clockwise in the surface layer. Anyway, the embayed situation of the Gulf, the dominant winds blowing offshore (from North-East) and very shallow waters create a quite sheltered condition (PANNACIULLI & RELINI, 2000).

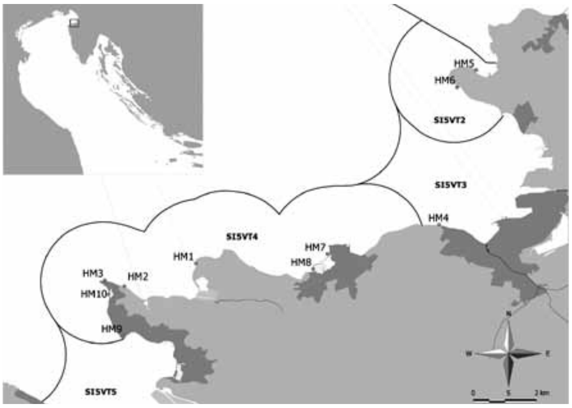

*Fig. 1. The map of the study area with sampling sites (HM1 - HM10) and boundaries of Slovenian coastal Water Bodies (SI5VT2-SI5VT5)*

The coastal morphology of the Gulf varies from steep rocky cliffs to gradual sloping beaches made of gravel and pebbles. With respect to its sedimentary structure, the substrate of the Gulf is clayey silt (with 10 – 20 % of clay), which on the coast turns into silty clays (with up to 25 % of clay), while in the direction of the open sea it turns into fine sand (OGORELEC *et al.*, 1991). The rocky substratum of the Slovenian coast consists mainly of Eocene flysch layers, with alternating solid sandstone and soft marl (OGORELEC *et al.*, 1997).

The Slovenian coastal sea, a shallow semi-enclosed embayment, covers the southern part of the Gulf of Trieste (Fig. 1). The maximum depth (33 m cca) is reached in waters off Piran. The shore has a generally regular outline with two main bays: Koper bay and Piran bay – which are wide submerged valleys of the rivers Rižana and Dragonja, respectively (TURK, 1999). In recent decades the Slovenian coastal sea has suffered from many anthropogenic impacts such as intensive farming, mariculture, overfishing, urbanization and massive tourism. These activities contributed in destroying or changing the natural shoreline and nowadays only 18% of the coastline is still in natural state urbanization (TURK, 1999).

Ten different sampling sites were chosen along the Slovenian coast (Fig.1) and subdivided into classes of hydromorfological modifi-

*Table 1. Sampling sites and a-priori classification into classes of HM alterations.*

| **Code** | **Coastal modification** | **Location** | **Type of substrate** | **Water retention** | **Classes of HM alterations** |
|---|---|---|---|---|---|
| HM1 | Reference | Natural Reserve Strunjan | Gradual slope, pebbles, rocks | Minimum | High |
| HM2 | Reference | Fiesa | Gradual slope, pebbles, rocks, natural sandstone boulders | Minimum | High |
| HM3 | Slightly stressed | Cape Madona | Vertical breakwaters, big allochtonous limestone boulders | Minimum | Good |
| HM4 | Slightly stressed | Coastal road Koper-Izola | Vertical breakwaters, big allochtonous limestone boulders | Minimum | Good |
| HM5 | Slightly stressed | Police beach Debeli rtič | Concrete wall, gradual slope, rocks, pebbles, sand, allochtonous limestone and natural sandstone boulders | Medium | Good |
| HM6 | Moderately stressed | Youth Health & Holiday Center Rdeči Križ | Concrete wall, big allochtonous limestone boulders | Minimum | Moderate |
| HM8 | Moderately stressed | Breakwater in marine of Izola | Big allochtonous limestone boulders | Minimum | Moderate |
| HM7 | Heavily stressed | Customs' dock in Izola | Concrete wall | Medium | Poor |
| HM9 | Very heavily stressed | Laguna Bernardin | Concrete pier, boat mooring | Maximum | Bad |
| HM10 | Very heavily stressed | Piran port | Concrete pier, boat mooring | Maximum | Bad |

*Table 2. Horizontal extent of upper and lower mediolittoral zones in the sampling sites*

| Code | Coastal modification | Subbelt horizontal extent (m) | |
|---|---|---|---|
| | | Upper mediolittoral | Lower mediolittoral |
| HM1 | Reference | 1.60 | 6.10 |
| HM2 | Reference | 4.90 | 8.10 |
| HM3 | Slightly stressed | 3.30 | 2.30 |
| HM4 | Slightly stressed | 1.20 | 2.50 |
| HM5 | Slightly stressed | 2.00 | 7.00 |
| HM6 | Moderately stressed | 0.60 | 0.30 |
| HM7 | Heavily stressed | 0.45 | 0.55 |
| HM8 | Moderately stressed | 0.60 | 1.40 |
| HM9 | Very heavily stressed | 0.50 | 0.40 |
| HM10 | Very heavily stressed | 0.55 | 0.35 |

cation, from pristine conditions to very heavily stressed zones (according to the WFD). They were chosen through the evaluation of coastal modifications, due to an abiotic stressor gradient, that includes: material, texture, structure, belt extension and water retention (see ORLANDO-BONACA *et al*., 2012). Two sites were initially identified for each class, but eventually the pre-classification of the status of two of them was corrected, because *in situ* observations revealed different conditions (HM5 and HM8). As a result only one site correspond to class 4, and three sites correspond to class 2 ( Table1). As reference sites were chosen the Natural Reserve of Strunjan (HM1) and the coast under Piran natural cliffs (HM2). Slightly stressed sites were Cape Madona Nature Monument (HM3), a segment of the coast between Koper and Izola (HM4), and the Police seaside resort of Debeli Rtič (HM5). Moderately stressed sites were located in the Youth Health and Holiday Center Rdeči Križ (HM6) and at the external breakwaters of the Marina of Izola (HM8). The only heavily stressed location was the Customs' dock in Izola (HM7), while very heavily stressed sites were inside the small ports of Bernardin (HM9) and Piran (HM10).

## Field work

The fieldwork was carried out by SCUBA diving and snorkeling in June 2008, during high tide, which represent the best conditions for collecting vagile organisms, such as more active animals (crabs, isopods, amphipods and gastropods). Sampling collection procedure was in accordance with BIANCHI *et al.* (2003).

Horizontal extent of upper and lower mediolittoral was determined through organisms' observation, according to SPECCHI (1966), GAMULIN-BRIDA (1967), PÉRÈS (1967) and BELLAN-SANTINI *et al.* (2002), and measured ( Table2). The vertical extent of the whole mediolittoral belt was approximately 0.9 m.

For each location 10 replicates were collected, 5 in the upper and 5 in the lower mediolittoral belt. Sampling was carried out to obtain a representative picture of the variety of microhabitats present in each site.

Samples were collected by scraping off with a spatula a square of 20 x 20 cm, a surface which is frequently used in Mediterranean benthic ecology (BIANCHI *et al.*, 2003, RINDI & BATTELLI, 2005).

Photos of each square were taken with a digital camera, before and after animals' collection, in order to obtain data on substrate characteristics and to monitor the accurateness of the operation. The material was sieved through a 0.5 mm mesh and fixed immediately after collection with ethanol 97% diluted to 70% in seawater.

### Laboratory work

In the laboratory samples were again sieved through a 1 mm mesh and carefully sorted. Each group was preserved in 70% ethanol. All organisms (Amphipoda excluded) were identified to the lowest feasible taxonomic level according to: TEBBLE (1966), PARENZAN (1970, 1974, 1976), Torelli (1982), COSSIGNANI *et al.* (1992) and DE MIN & VIO (1997) for mollusks; FAUVEL (1923, 1927) for polychaetes; BATTELLI AND DOLENC-ORBANIĆ (2009) for cirripedia; NAYLOR (1972) and HARRISON & ELLIS (1991) for isopods; RIEDL (1991), FALCIAI & MINERVINI (1992) and HAYWARD and RYLAND (1995) for other crustaceans; OCCHIPINTI (1981) for bryozoans. The nomenclature followed COSTELLO *et al.* (2008). The Amphipods were only counted in total, since they required specialist knowledge to be determined to the species level and, due to their species richness and abundance; this work would have been very time-consuming.

The number of organisms was determined counting only specimens that were alive at the time of collection. For colonial species of bryozoans and algae the percentage of cover was determined instead of the number of individuals. The surface covered by each species was quantified in cm$^2$ (4 cm$^2$ = 1% of the sampling surface). Only colonies covering at least 1% of the sampling area were assessed.

Macroalgae were taken into consideration as they create important microhabitats for macrozoobenthic species. Species of macroalgae were identified in laboratory by using a binocular microscope and a microscope in accordance with GOMEZ GARRETA *et al.* (2001), RIBERA *et al.* (1992), BRESSAN & BABBINI (2003) and GALLARDO *et al.* (1993),. Each sample was sorted carefully and the surface covered by each species was determined as for bryozoans.

Bottom substrate composition was visually estimated first in the field after organisms' collection; secondly those estimations were verified in the laboratory through the analysis of the photo documentation taken in the field. Each photo was divided into 100 equal parts with the help of a grid and examined in order to identify percentages of substrate components [boulders (1 - 2 m; 0.50 – 1 m), rocks (10 - 50 cm; 2- 10 cm), pebbles (0.2 – 2 cm), and sand (0.05 - 2 mm)] and rugosity (1=flat or almost flat substrate, with no holes; 2=almost flat with shallow holes and cracks; 3=undulate, corroded concrete or boulder; 4=very corroded concrete or boulder, with deep holes; 5=rocks, pebbles).

Water retention (from normal hydrology in unprotected coast to closed areas with only one opening) was assessed through *expert judgment*, observing the geomorphology of the area and knowing currents and wave action.

Feeding guilds were determined using: BACHELET (1981), SOLIS-WEISS *et al.* (2004) and DONEDDU & TRAINITO (2005) for molluscs; FAUVEL (1923, 1927) and SOLIS-WEISS *et al.* (2004) for polychetes; RIEDL (1991) and BATTELLI & DOLENC-ORBANIĆ (2009) for Cirripedia; NAYLOR (1972), HARRISON AND ELLIS (1991) and RIEDL (1991) for isopods; RIEDL (1991), FALCIAI & MINERVINI (1992) and HAYWARD & RYLAND (1995) for other crustaceans; OCCHIPINTI (1981) and RIEDL (1991) for bryozoans.

### Data analysis

The total number of species ($S$) and the relative abundance (%) were calculated.

In order to evaluate different components of biodiversity, different types of indices were calculated for each site: Margalef index of richness ($d$), Pielou index of equitability ($J'$), Shannon & Wiener diversity index on $log_2$ basis ($H'$) and Simpson-Gini index of dominance ($D_\lambda=1-\lambda$). The software used was PRIMER (Plymouth Routines In Multivariate Ecological Research) version 6.1.5. Bryozoans couldn't be considered for abundance and univariate indices calculations, since the percentage of cover was calculated instead of the number of individuals.

Cluster analysis was applied to the dataset of macrozoobenthos total abundances for each site, in both, upper and lower mediolittoral belts.

Data were *log(x+1)* transformed to reduce the weight of the dominant species. Bray-Curtis dissimilarity coefficient was used to build the similarity matrix and the hierarchical classification algorithm of unweighted pair group average was applied.

Non-transformed abundances and quantified environmental variables were subjected to Canonical Correspondence Analysis (CCA) (TER BRAAK, 1986), using the package CANOCO for Windows version 4.5, in order to evaluate interspecific differences in habitat use.

This method was applied to the upper and lower mediolittoral subbelts, separately. For the upper mediolittoral belt, the entire species data set and 14 environmental variables were used. For the lower mediolittoral belt, to avoid overcrowding of points on the graph, only species with more than 10% of the total occurrences were included, with data for 15 environmental variables.

In order to analyze the community structure, K-dominance curves, using PRIMER 6.1.5, were made.

One way ANOSIM (Analysis Of SIMilarities), was applied to Bray-Curtis values of species abundances to test the significance of differences among the two subbelts, the significance of differences between the group of high-good sites (HM1-5) and the group of poor-moderate-bad sites (HM6-10) and to check whether the variability among replicate samples was smaller than the variability among sites, in both upper and lower mediolittoral subbelts.

*Table 3. Structural indexes values in each station, in the upper (HM1-10up) and lower (HM1-10low) mediolittoral belt. S= number of species; N= abundance; d= Margalef index; J'= Pielou index; H'=Shannon-Wiener diversity index; 1-λ'= Simpson dominance index*

| **Station** | ***S*** | ***N*** | ***d*** | ***J'*** | ***H'*** | ***1-λ'*** |
|---|---|---|---|---|---|---|
| HM1up | 9 | 54 | 2.01 | 0.85 | 2.71 | 0.84 |
| HM1low | 22 | 152 | 4.18 | 0.75 | 3.33 | 0.86 |
| HM2up | 5 | 143 | 0.81 | 0.48 | 1.12 | 0.42 |
| HM2low | 19 | 176 | 3.48 | 0.83 | 3.53 | 0.89 |
| HM3up | 6 | 341 | 0.86 | 0.33 | 0.86 | 0.29 |
| HM3low | 14 | 795 | 1.95 | 0.36 | 1.37 | 0.40 |
| HM4up | 5 | 113 | 0.85 | 0.15 | 0.35 | 0.09 |
| HM4low | 27 | 2690 | 3.29 | 0.23 | 1.09 | 0.28 |
| HM5up | 10 | 306 | 1.57 | 0.35 | 1.16 | 0.34 |
| HM5low | 43 | 2231 | 5.45 | 0.44 | 2.41 | 0.66 |
| HM6up | 8 | 1355 | 0.97 | 0.18 | 0.55 | 0.17 |
| HM6low | 16 | 921 | 2.20 | 0.32 | 1.28 | 0.35 |
| HM7up | 6 | 102 | 1.08 | 0.33 | 0.85 | 0.25 |
| HM7low | 18 | 1688 | 2.29 | 0.25 | 1.03 | 0.32 |
| HM8up | 8 | 260 | 1.26 | 0.40 | 1.20 | 0.44 |
| HM8low | 25 | 472 | 3.90 | 0.50 | 2.33 | 0.60 |
| HM9up | 5 | 433 | 0.66 | 0.50 | 1.16 | 0.44 |
| HM9low | 24 | 637 | 3.56 | 0.49 | 2.27 | 0.68 |
| HM10up | 6 | 66 | 1.19 | 0.25 | 0.64 | 0.17 |
| HM10low | 16 | 1443 | 2.06 | 0.35 | 1.39 | 0.41 |

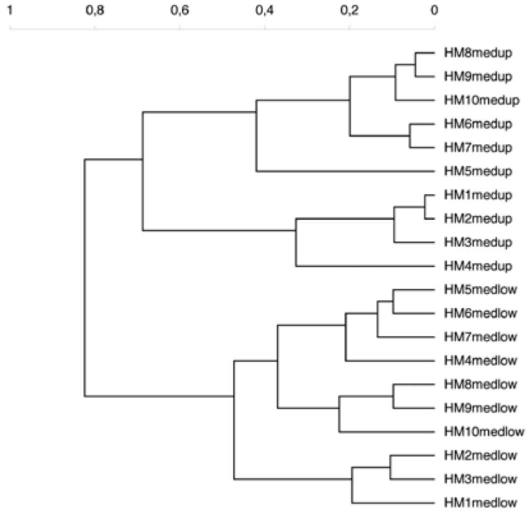

*Fig. 2. Cluster analysis for the total abundances data in each station of the upper (HM1medup-HM10medup) and lower (HM1medlow-HM10medlow) mediolittoral belt*

## RESULTS

### Faunistic and ecological overview

In the mediolittoral belt of 10 sampling sites, 140 taxa of invertebrates were determined (36 in the upper and 131 in the lower mediolittoral subbbelts), 94 of them to the species level (24 in the upper and 89 in the lower subbelts). They belong to 6 different phyla: Arthropoda, Mollusca, Anellida, Echinodermata, Bryozoa and Cnidaria ( Table A1).

Moreover, 28 species of macroalgae were determined, 14 were found in the upper and 27 in the lower mediolittoral subbelt ( Table A2).

Number of taxa were more or less equally distributed among the three main phyla (Arthropoda, Mollusca and Anellida), with only a few percentage (<5%) of other phyla. There were no relevant differences among the two subbelts. In the upper part Arthropoda were the most abundant (38%) followed by Mollusca (31%) and Polychaeta (25%); in the lower part Mollusca were the most abundant (35%) followed by Polychaeta (33%) and Arthropoda (26%).

Regarding species abundance, 16,102 individuals were found (3,603 in the upper and 12,498 in the lower mediolittoral belt). In the upper mediolittoral belt the most abundant phylum was Arthropoda (approximately 89%), followed by Mollusca (approximately 10%). In the lower mediolittoral belt Mollusca taxa were dominant (approximately 77%), followed by Arthropoda (approximately 18%). Other phyla were present with a very low percentage of abundance.

In the upper mediolittoral belt the dominant arthropods were species of the genus *Chthamalus*, while the high abundance of mollusks was mainly due to the presence of the supralittoral species *Melarhaphe neritoides* and juveniles of *Mytilus galloprovincialis*. In the lower mediolittoral belt the high abundance of mollusks was mainly due to juveniles of *M. galloprovincialis*, while the abundance of Arthropoda was mainly due to Amphipoda, Cirripedia and Tanaidacea.

*Table 4. Summary of ANOSIM test results*

| | Sample statistic (Global R) | Significance level of sample statistic | Number of permutations |
|---|---|---|---|
| Differences between subbelts | 0.864 | 0.0001% | 92378 (all possible) |
| High-good *vs* moderate-poor-bad status (upper mediolittoral) | -0.06 | 7.3% | 126 (all possible) |
| High-good *vs* moderate-poor-bad status (lower mediolittoral) | 0.04 | 0.08% | 126 (all possible) |
| Differences among replicates (upper mediolittoral) | 0.34 | 0.00001% | 1000000 (random) |
| Differences among replicates (lower mediolittoral) | 0.466 | 0.00001% | 1000000 (random) |

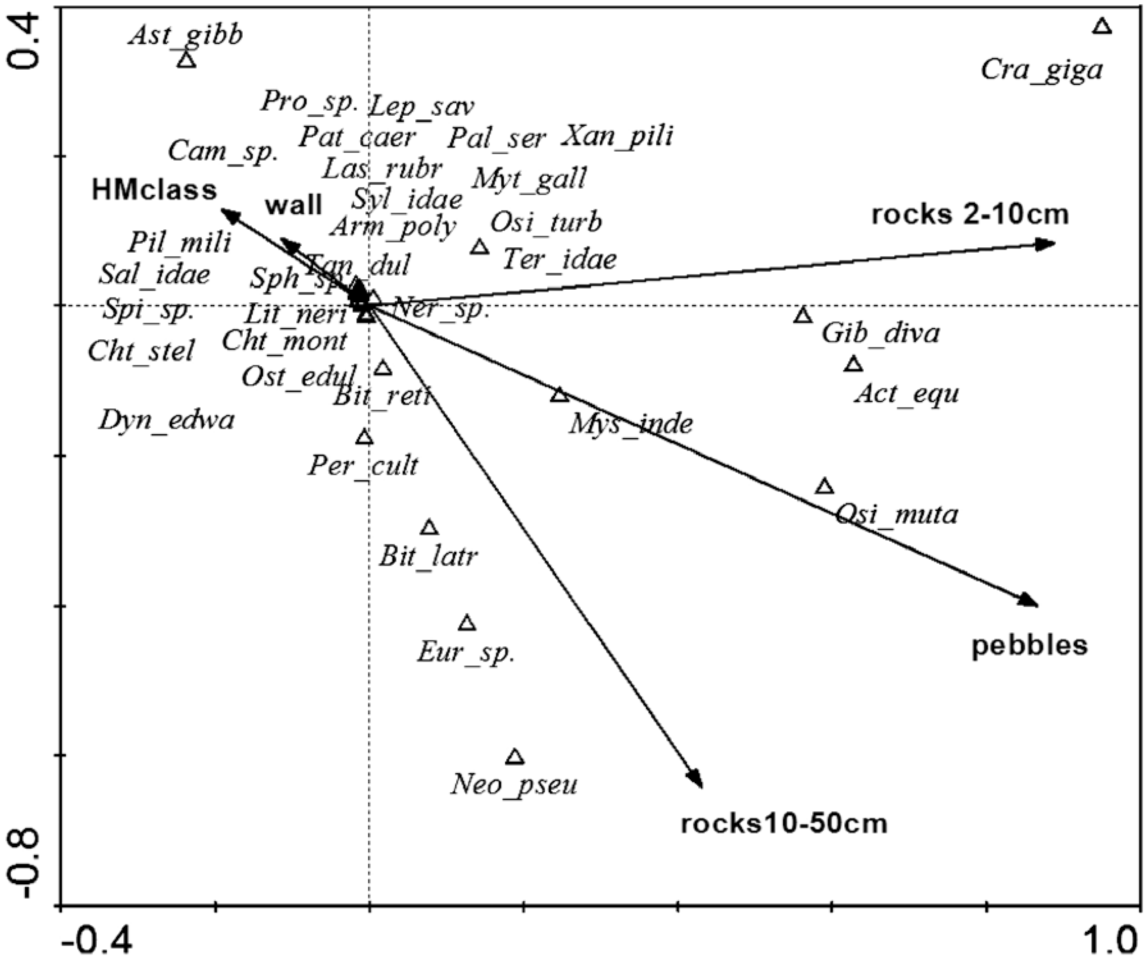

*Fig. 3. CCA ordination diagram showing relationship between macrozoobenthos species abundances and environmental variables in the upper mediolittoral subbelt. Only axes 1 and 2 are presented, as they cumulatively account for 68% of the total variance. The species-environmental correlations of each axis were 0.66 (axis 1) and 0.35 (axis 2). All macrozoobenthos species were used and only variables statistically correlated with macrozobenthos assemblages are shown. Species codes are presented in table A1.*

Species richness was always lower in the upper mediolittoral than in the lower sub-belt, and differences among sites were less marked ( Table3).

Regarding the number of individuals, values in the lower mediolittoral were always higher than in the upper mediolittoral - with the exception of HM6 - and there were marked variations among sites, within both subbelts ( Table3).

From the cluster analysis on the data set of macrozoobenthos total abundances (Fig. 2), with a cut at 70% level of dissimilarity, sites were clearly divided into two groups, corresponding to the two subbelts. The one way ANOSIM test showed that this difference is highly significant (R=0.864, P=0.0001) ( Table4).

The results of the cluster analysis on the upper mediolittoral subbelt (Fig. 2) allowed the distinction of two groups of sites (with a cut at the 50% of dissimilarity): one with sites from HM1 to HM4, which are sites considered as high and good status, and one with the others.

The results of the cluster analysis on the lower mediolittoral subbelt (Fig. 2) defines three main groups of sites (with a cut at the 30% of dissimilarity): the first with HM1, HM2 and HM3 (high and good status), the second with HM8, HM9 and HM10 (moderate and bad status) and the third with sites HM4, HM5, HM6, HM7 (good, moderate and poor status) (Table4).

Determined species were grouped into 6 different feeding guilds: filtrators, grazers, predators, detritivores, opportunistic and parasites. Species were considered as opportunistic if they have more than one method of feeding. In the upper mediolittoral belt grazers represent 42% of total number of species, filtrators 33%, opportunistic 13% and predators 4%. Considering the abundance of species belonging to different trophic categories, filtrators resulted to be the most represented with 93% of total number of individuals, followed by grazers with 6%, while opportunistic and predators represent less than 1%. Filter-feeding were mainly chthamalids (*C. montagui* and *C. stellatus*) and mussels (*M. galloprovincialis*), while grazers were mainly gastropods (M. *neritoides, P. caerulea, Osilinus turbinatus, O. mutabilis* and *Bittium latreilli*)In the lower mediolittoral belt grazers represented 27% of total number of species,

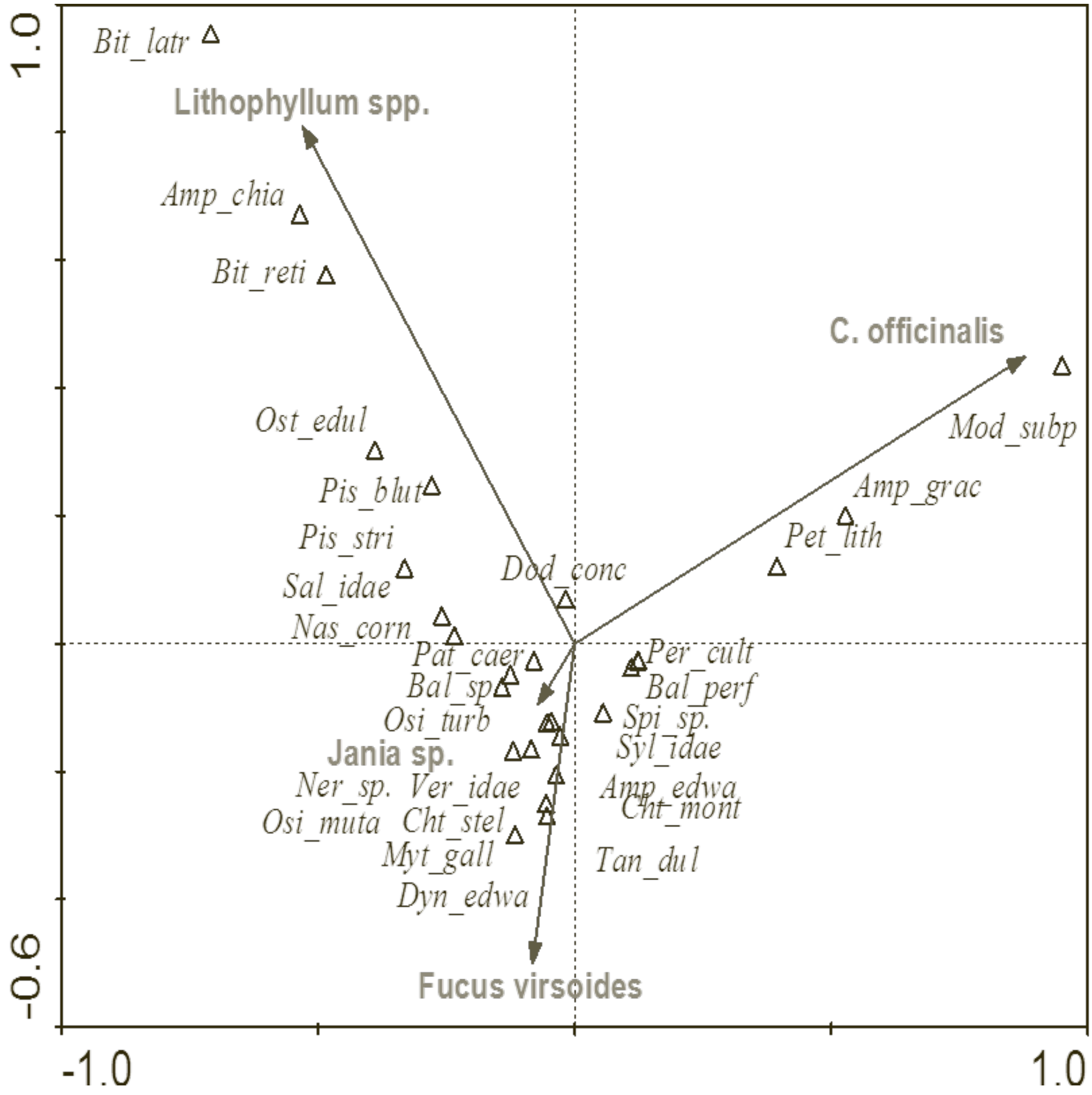

*Fig. 4. CCA ordination diagram showing relationship between macrozoobenthos species abundances and environmental biotic variables (algal coverage) in the lower mediolittoral subbelt. Only axes 1 and 2 are presented, as they cumulatively account for 76% of the total variance. The species-environmental correlations of each axis were 0.47 (axis 1) and 0.39 (axis 2). Only species present in more than 10% of samples were used, and variables significantly correlated with assemblages are shown. Species codes are presented in table A1*

followed by filtrators with 23%, predators with 21%, detritivores 15%, opportunistic with 13% and parasites with 1%. Considering the abundance of species, filtrators again resulted to be the most represented were with 72% of total number of individuals, followed by grazers with 21%, opportunistics with 4%, predators with 2%, detritivores with 1% and parasites with less than 1%

Filtrators were mostly bivalves (chiefly *M. galloprovincilis* and *Modiolarca subpicta*) and barnacles (*B. perforatus*). Grazers were mainly gastropods (*B. reticulatum*, *B. latreilli* and many of the family Trochidae) and isopods (chiefly *Dynamene edwardsii*).

Predators were mainly gastropods Muricidae (*Hexaplex trunculus* and *Ocinebrina edwardsii*) and Nassaridae (*Nassarius corniculus* and *N.*

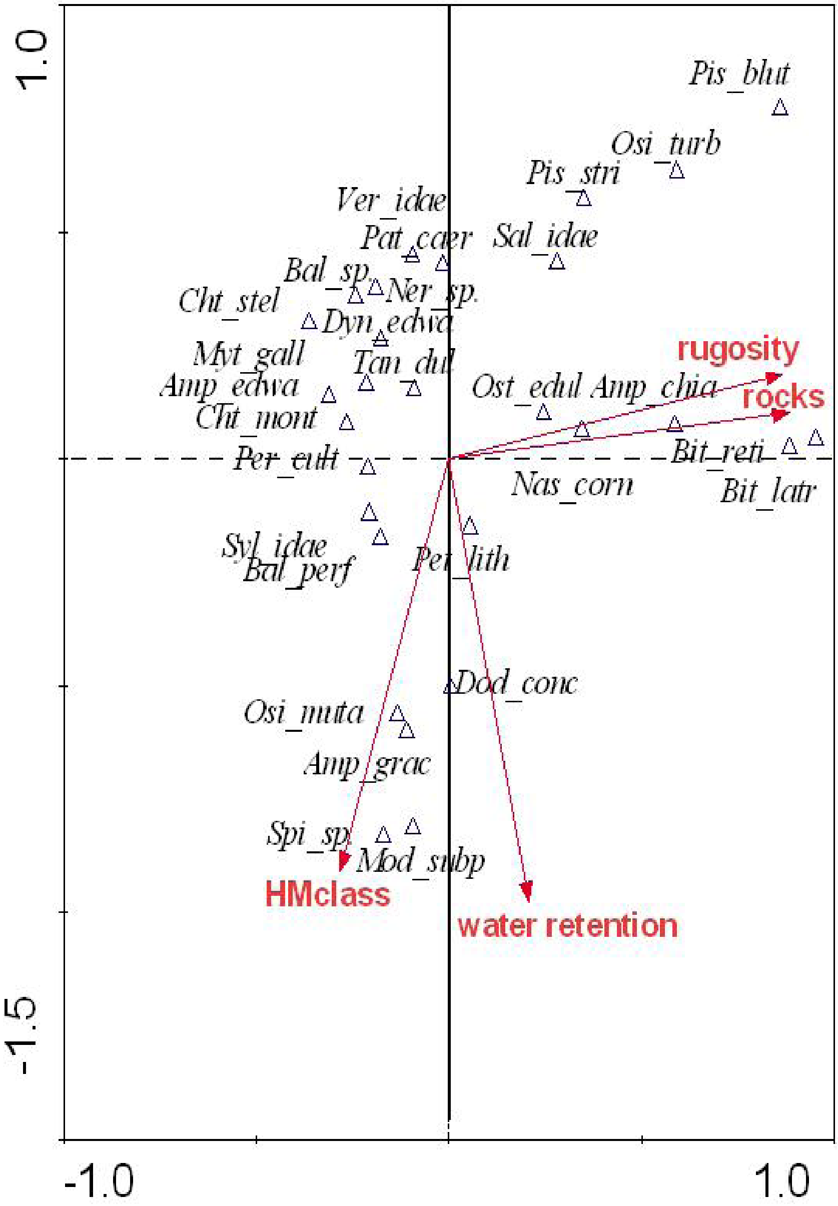

*Fig. 5. CCA ordination diagram showing relationship between macrozoobenthos species abundances and environmental abiotic variables in the lower mediolittoral subbelt. Only axes 1 and 2 are presented, as they cumulatively account for 81% of the total variance. The species-environmental correlations of each axis were 0.75 (axis 1) and 0.48 (axis 2). Only species present in more than 10% of samples were used and variables significantly correlated with assemblages are shown. Species codes are presented in table A1*

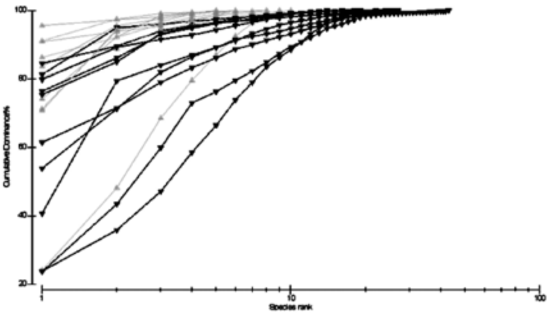

*Fig. 6. K-dominance curves of different stations in the upper (grey lines) and lower (dark lines) mediolittoral belt*

*incrassatus*), many polychaetes (mainly Phyllodocidae, Syllidae, Nereididae and Lumbrinereidae) and some crustaceans (*Athanas nitiscens, Thoralus cranchi* and *Porcellana platycheles*). Among detritivores there were mainly polychaetes (Spionidae, Cirratulidae, Terebellidae) and echinoderms (*A. chiajei* and *Amphipholis squamata*).

The most frequent species in *high* and *good* sites were grazers (*B. reticulatum, O. turbinatus, D. edwardsi, P. caerulea*), detritivores and filtrators (*T. dulongii*) and predators (*N. corniculus* and *P. striata*).

### Environmental factors

The main pattern of variation in the macrozoobenthos assemblage composition as accounted for by the environmental variables was investigated with CCA analysis. For the upper mediolittoral subbelt a diagram (Fig. 3) was obtained with all macrozoobenthos species found. Only axes 1 and 2 are presented, as they cumulatively account for 68% of the total variance. The species-environmental correlations of each axis were 0.66 (axis 1) and 0.35 (axis 2). A set of species resulted associated to rocks and pebbles (negatively correlated with the presence of vertical walls), while other species are not showing a real preference for any environmental variable.

For the lower mediolittoral subbelt species present in more then 10% of samples were used to obtain two diagrams, one with biotic variables (Fig. 4) and one with abiotic variables (Fig. 5). Only axes 1 and 2 are presented, as they cumulatively account for 76% of the total variance in figure 4 and 81% of the total variance in Fig. 5. The species-environmental correlations of each axis were 0.47 (axis 1) and 0.39 (axis 2) in figure.4 and 0.75 (axis 1) and 0.48 (axis 2) in figure 5. Considering biotic variables (Fig.4), a first set of species are associated with sites where coralline algae of the genus *Lithophyllum* are present and a second group shows a preference for sites with *Corallina officinalis (L.).* With regard to abiotic variables (Fig. 5), a first set of species are associated with high levels of water retention and increasing hydromorphological modification, a second set is positively correlated with the increasing rugosity of the substratum and the presence of rocks and pebbles. Eventually, a third set of species shows a negative correlation with the increasing water retaining and hydromorphological modification. Most of these species were also found on substrata with low levels of rugosity.

The communities in the mediolittoral belt are rather poorly structured, as shown by the K-dominance curves and there is a clear difference between the two subbelt (Fig.6). With the exception of site HM1, in the upper mediolittoral belt curves are rather flat and short, due to a low number of species and the fact that one or two species made up most of the total abundance. In the lower mediolittoral subbelt the curves are longer (due to a higher species richness), and they reach the asymptote more slowly (abundances better distributed). Both subbelts of site HM1 and the lower mediolittoral of site HM2 are represented by curves with the lowest initial dominance, indicating that they present the highest structured communities, with abundances well distributed among species.

The one way ANOSIM test shows that differences among the two subbelts are statistically significant (R=0.864, P=0.0001) ( Table4).

## DISCUSSION

### Diversity response to hydromorphological variables

Intertidal rocks represent a stressful environment for benthic organisms. It is more or less regularly exposed and submerged according to sea level variations due to tides, winds and atmospheric pressure. Humectation is the most important limiting factor structuring communities in this belt. In the upper mediolittoral it arises largely from waves and submergence is rare, whereas in the lower subbelt submergence occurs more frequently and sometimes for rather longer periods (PÉRÈS, 1967). Consequently lower mediolittoral communities show higher values of species richness, abundances, evenness and overall diversity compared with the upper mediolittoral. This result was expected, since in the upper subbelt organisms live in more extreme conditions. They are subjected to longer periods of emersion and are more subjected to desiccation and extreme temperatures (SPECCHI, 1966; PÉRÈS, 1967; SPECCHI & OREL, 1969; UNDERWOOD, 1981; OREL, 1991; FINKE *et al.,* 2007; VALDIVIA *et al*., 2011).

Despite these natural differences between upper and lower mediolittoral subbelts, univariate and multivariate analysis seems to indicate that human-induced alterations of the coastal zone associated with human disturbance influence littoral conditions and consequently impact biological assemblages.

In the present work there is a marked difference in diversity (Shannon-Wiener diversity as well as Simpson) among sites with a *high* ES (HM1 up, HM1 low and HM2 low) and the others. This high diversity is mainly due to evenness of species distribution (as Pielou and Simpson indices showed), rather than species richness. These results are consistent with K-dominance curves: sites with the highest diversity (HM1 up, HM1 low and HM2 low) were the only one that showed a well structured community, with the lowest value for the most dominant taxon (<30%).

The highest richness and abundance are found in Good/Moderate sites, slightly or moderately affected by anthropogenic disturbance. The peculiarity of these sites is consistent with intermediate disturbance hypothesis (DIAL & ROUGHGARDEN, 1998; TOKESHI, 1999, SVENSSON *et al.*, 2012). High abundance values in HM4low were mainly due to the dominant bivalve *M. galloprovincialis*. This species co-occur with a high coverage of the brown alga *Fucus virsoides (J.Agardh)*, as it was expected, since *M. galloprovincialis* is typically associated with this seaweed (GAMULIN-BRIDA, 1967; PÉRÈS, 1967). The low diversity for this site could be more likely the result of natural hydrological conditions (unprotected coast) which also favor *F. virsoides*, rather than a consequence of anthropogenic disturbance. Probably for that reason this site is not grouped with other High/Good sites.

### Abiotic factors structuring community

Some authors suggested that differences between natural rocks and artificial structures could be due to factors such as intrinsic properties of the surfaces (CHAPMAN, 2003) or position and orientation of the surface (GLASBY & CONNEL, 2001). In the present work no significant difference in benthic community between natural boulders made of sandstone and artificial boulders made of limestone of comparable size were found. At the same time, a clear correlation between some species and some substrate characteristic were underlined (CCA analysis). This suggests that structural complexity of the habitat (presence of rocks and pebbles, substrate rugosity) influences diversity more than chemical composition of the substrate. As suggested by SPECCHI (1966) and MCQUAID & BRANCH (1985), the dominance of unstable rocks and pebbles could result in low richness but high evenness and diversity, since no single group of species was able to dominate the community. Consistently with other works (BENEDETTI-CECCHI *et al.*, 2000), horizontal extension of subblets could also play a role in structuring community, so observed differences between natural shore with gradual slopes (wider extension) and artificial vertical walls were expected. According to our data, substrate complexity plays a major role in structuring community in the upper mediolittoral subbelt.

Urban and industrial development comport also a local modification of water circulation. In particular, hard coastal-defense structures, such as breakwaters, can provide sheltered habitats along wave-exposed coasts. Wave-exposure is an important determinant of the structure of benthic assemblages (UNDERWOOD, 1981; HAWKINS, 1983; MENGE *et al.*, 1993; DENNY, 1995; DAVIS *et al.*, 2002). The present study shows that in the lower mediolittoral subbelt, not only substrate characteristic but also changes in water retention play a role in modifying species assemblages.

Our results underline the importance of local substrate characteristics for the distribution of the benthic community in both mediolittoral subbelts. Abiotic factors could favor the species in two ways: they could eliminate main competitors, permitting the development of others species, or they could reduce the action of predators and grazers, favoring dominant competitors.

### Biotic factors structuring community

Consistently with the pattern described by other authors (BARNES & HUGHES, 1990; BERTNESS *et al.,* 1999), our results show that in the upper mediolittoral subbelt abiotic factors play a major role in structuring the community. In fact, in the upper subbelt a low algal coverage was found, and predators where almost absent. The main biotic factor that influences the community structures in this subbelt is probably competition among sessile animals for the substrate to colonize.

Nevertheless, the role of grazers in structuring seaweed community in the upper subbelt could be relevant, since they feed on sporelings. PAINE (1984) concluded that grazers can in such way promote the coexistence of different seaweeds. Grazing activity of species, such as *Patella* sp., could influence also the density of sessile invertebrates (e.g. barnacles), as they can feed on their larvae together with sporelings and microalgae (BARNES & HUGES, 1990). In the present work, *M. neritoides* was among the most abundant grazers of the upper mediolittoral belt. During high tides periods this gastropod, typical species of the supralittoral belt, moves for feeding in the upper part of the underlying mediolittoral.

Desiccation and high temperature in the upper subbelt prevent *Balanus* species from settling higher on the coast, leaving space for chthamalids (BARNES & HUGES, 1990). During our study *Balanus* species, in fact, were not found in the upper mediolittoral, while only few chthamalids were present in the lower mediolittoral.

Seaweeds presence in the lower mediolittoral belt resulted more significant and contribute to structure the community. BRANCH (1984) suggested that sessile filter-feeders and algae are most likely to compete for space and can readily monopolise a habitat. In the present work, this was not observed. Both filter-feeders and seaweed were quite abundant in the lower mediolittoral, so an equilibrium have been established among them. Macroalgae could also favor intertidal animals through habitat modification. Likely, their most crucial role in the intertidal zones consists in ameliorating thermal and desiccation stresses (BERTNESS *et al.,* 1999). Beside the action of grazers, in the lower subbelt the presence of many predators inevitably affected the community.

### Hydromorphological modification and impact assessment

Up to date, hydromorphological alterations were very often excluded from assessment methods of coastal waters (like from WFD-compliant assessment systems). Only recently, a new index called BIRS was developed to addresses morphological conditions, including use (bathing and walking) of the littoral and sublittoral belts of the coastal area (ORLANDO-BONACA *et al.*, 2012).

Other works pointed out that artificial structures support different benthic communities than natural rocky reefs, but those differences were not well defined (BACCHIOCCHI & AIROLDI, 2003; CHAPMAN, 2003; CHAPMAN & BULLERI, 2003).

We point out the presence in this work of the Pacific oyster, *Crassostrea gigas*, a species introduced in Europe for aquaculture purposes. This species could grow on both natural and artificial substrates. Some authors (BULLERI & AIROLDI, 2005; GLASBY & CONNELL, 2006; RUIZ *et al.,* 2009) concluded that increasing spreading of artificial structures could favor the dispersion of non-native species.

In the present work several hydromorphological variables describing habitat conditions and hydrology were considered (material, texture, structure of the bottom, belt extension, water retention). We are aware that the pool of potential drivers and stressors that can be included is larger, like the land use at a greater distance from the coastline, as well as seawater quality. Nevertheless, we believe that our variables encompass quite well the principal mechanisms in the mediolittoral belt of the study area.

The role played by human-induced activities on the status of benthic flora and fauna is usually difficult to assess, since both natural and anthropogenic factors take part in structuring benthic communities. Our results suggest a response of benthic invertebrate communities in relation to changes in hydromorphological conditions in the mediolittoral belt. The macrobenthic community on pristine sites resulted very different from that on heavily altered sites, as expected. The correctly assessed HM stressor gradient gave us an appropriate response. Anyhow, this response was complex, and the major human-induced alterations considered had different level of pressure within the two subbelts.

The current study has a good potential to contribute to existing coastal assessment methods, since the impact of hydromorphological pressures on mediolittoral communities was almost neglected in the past. However, further work is needed to fully explain the impact of main human-induced threats on benthic communities.

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# Stjenovita zajednica mediolitoralnog makrozoobentosa u Tršćanskom zaljevu (sjeverni Jadran) duž hidromorfološkog gradijenta

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## SAŽETAK

Unatoč rastućem urbanom i industrijskom razvoju u obalnim područjima samo nekolicina istraživača je fokusirana na direktne posljedice obalnih modifikacija na bentičke zajednice. Cilj ovog istraživanja je procijeniti odgovore stjenovitih zajednica mediolitoralnog makrozoobentosa na hidromorfološke pritiske. Uzorkovanje je provedeno ronjenjem sa bocama i ronjenjem na dah u lipnju 2008. godine. Izabrano je deset postaja duž hidromorfološkog gradijenta u južnom dijelu Tršćanskog zaljeva. Upotrebljavane varijable za razvoj gradijenta stresora bile su: zadržavanje vode, sastav supstrata, tekstura i naboranost. Unatoč prirodnim razlikama između gornjih i donjih mediolitoralnih podpojaseva, sadašnji rad je pokazao da promjene krajolika povezane sa ljudskim djelovanjem u obalnoj zoni utječu na biološke cjeline. Postoji značajna razlika u bioraznolikosti između postaja s odličnim ekološkim stanjem i ostalih postaja, uglavnom zbog ravnomjerne rasprostranjenosti vrsta. Strukturna složenost supstrata rezultatirala je time da je bila glavni čimbenik koji utječe na raznolikost bentosa u gornjem mediolitoralnom podpojasu, dok je izgleda u donjem podpojasu ili podregiji također cirkulacija vode odigrala ključnu ulogu (CCA analiza). Odgovor bentičke zajednice bio je kompleksan i vjerojatno su također biotički čimbenici (pokrivenost algama, kompeticija) bili uključeni. Ovo istraživanje ima dobar potencijal da doprinese postojećim metodama procjene obale, iako se treba provesti daljnje istraživanje na području utjecaja kojeg imaju hidromorfološke promjene na obalne bentičke zajednice.

**Ključne riječi:** makrozoobentos, tvrdo dno, mediolitoralni pojas, hidromorfološki uvjeti, ekološki aspekt, uvjeti, Tršćanski zaljev

# Appendix

*Table A1. Faunistic list in systematic order, with feeding guilds (F=filtrators, G=grazers, O=opportunistics, D=detritivores, P=predators, Pa=parasites) in the upper and lower mediolittoral*

| **Phylum** | **Taxon** | **Code** | **Feeding guild** | **Upper subbelt** | **Lower subbelt** |
|---|---|---|---|---|---|
| Cnidaria | *Actinia equina* (Linnaeus, 1758) | *Act_equ* | O | X | |
| Mollusca | *Ischnochiton rissoi* (Payraudeau, 1826) | *Isc_riss* | G | | X |
| Mollusca | *Chiton (Rhyssoplax) olivaceus* (Spengler, 1797) | *Chi_oliv* | G | | X |
| Mollusca | *Acanthochitona fascicularis* (Linnaeus, 1767) | *Aca_fasc* | G | | X |
| Mollusca | *Patella caerulea* (Linnaeus, 1758) | *Pat_caer* | G | X | X |
| Mollusca | *Tricolia pullus* (Linnaeus, 1758) | *Tri_pull* | G | | X |
| Mollusca | *Gibbula adansonii* (Payraudeau, 1826) | *Gib_adan* | G | | X |
| Mollusca | *Gibbula adriatica* (Philippi, 1844) | *Gib_adri* | G | | X |
| Mollusca | *Gibbula divaricata* (Linnaeus, 1758) | *Gib_diva* | G | X | X |
| Mollusca | *Gibbula* sp. (juv.) Risso, 1826 | *Gib_sp-j* | G | | X |
| Mollusca | *Gibbula* sp. (juv.) (cfr. *adansonii)* | *Gib_sp-a* | G | | X |
| Mollusca | *Phorcus turbinatus* (Born, 1778) | *Osi_muta* | G | X | X |
| Mollusca | *Phorcus mutabilis* (Philippi, 1846) | *Osi_turb* | G | X | X |
| Mollusca | *Jujubinus exasperatus* (Pennant, 1777) | *Juj_exas* | G | | X |
| Mollusca | *Calliostoma laugieri* (Payraudeau, 1826) | *Cal_laug* | P | | X |
| Mollusca | *Rissoa variabilis* (Von Mühlfeldt, 1824) | *Ris_guer* | G | | X |
| Mollusca | *Rissoa* sp. (Desmarest, 1814) | *Ris_sp.* | G | | X |
| Mollusca | *Alvania cimex* (Linnaeus, 1758) | *Alv_cime* | G | | X |
| Mollusca | *Alvania discors* (Allan, 1818) | *Alv_disc* | G | | X |
| Mollusca | *Cerithium* sp. (juv.) Bruguière, 1789 | *Cer_sp-j* | G | | X |
| Mollusca | *Bittium latreillii* (Payraudeau, 1826) | *Bit_latr* | G | X | X |
| Mollusca | *Bittium reticulatum* (da Costa, 1778) | *Bit_reti* | G | X | X |
| Mollusca | Vermetidae indet. Rafinesque, 1815 | *Ver_idae* | F | | X |
| Mollusca | *Melarhaphe neritoides* (Linnaeus, 1758) | *Lit_neri* | G | X | X |
| Mollusca | *Truncatella subcylindrica* (Linnaeus, 1767) | *Tru_subc* | G | | X |

| | | | | | |
|---|---|---|---|---|---|
| Mollusca | *Marshallora adversa* (Montagu, 1803) | *Mar_adve* | P | | X |
| Mollusca | *Hexaplex trunculus* (Linnaeus, 1758) | *Hex_trun* | P | | X |
| Mollusca | *Ocinebrina edwardsii* (Payraudeau, 1826) | *Oci_edwa* | P | | X |
| Mollusca | *Pisania striata* (Gmelin, 1791) | *Pis_stri* | P | | X |
| Mollusca | *Columbella rustica* (Linnaeus, 1758) | *Col_rust* | G | | X |
| Mollusca | *Nassarius corniculum* (Olivi, 1792) | *Nas_corn* | P | | X |
| Mollusca | *Nassarius incrassatus* (Strøm, 1768) | *Nas_incr* | P | | X |
| Mollusca | Nudibranchia indet. (Cuvier, 1817) | *Nud_inde* | G | | X |
| Mollusca | *Mytilus galloprovincialis* (juv.) Lamarck, 1819 | *Myt_gall* | F | X | X |
| Mollusca | *Modiolus barbatus* (Linnaeus, 1758) | *Mod_barb* | F | | X |
| Mollusca | *Musculus subpictus* (Cantraine, 1835) | *Mod_subp* | F | | X |
| Mollusca | *Ostrea edulis* (Linnaeus, 1758) | *Ost_edul* | F | X | X |
| Mollusca | *Crassostrea gigas* (Thunberg, 1793) | *Cra_giga* | F | X | X |
| Mollusca | *Neopycnodonte cochlear* (Poli, 1795) | *Neo_coch* | F | | X |
| Mollusca | *Gastrana fragilis* (Linnaeus, 1758) | *Gas_frag* | D | | X |
| Mollusca | *Coralliophaga lithophagella* (Lamarck, 1819) | *Cor_lith* | F | | X |
| Mollusca | *Irus irus* (Linnaeus, 1758) | *Iru_irus* | F | | X |
| Mollusca | *Venerupis decussata* (Linnaeus, 1758) | *Tap_decu* | F | | X |
| Mollusca | *Venerupis* sp. (juv.) Lamarck, 1818 | *Tap_sp-j* | F | | X |
| Mollusca | *Petricola lithophaga* (Retzius, 1788) | *Pet_lith* | F | | X |
| Mollusca | *Hiatella rugosa* (Linnaeus, 1767) | *Hia_rugo* | F | | X |
| Mollusca | *Lasaea adansoni* (Gmelin, 1791) | *Las_rubr* | F | X | |
| Mollusca | Bivalvia indet. (Linnaeus, 1758) | *Biv_inde* | F | | X |
| Polychaeta | *Prionospio cirrifera* Wirén, 1883 | *Pri_cirr* | D | | X |
| Polychaeta | *Spio filicornis* (Müller, 1776) | *Spi_fili* | D | | X |
| Polychaeta | Cirratulidae indet. Carus, 1863 | *Cir_idae* | D | | X |
| Polychaeta | *Cirriformia filigera* (Delle Chiaje, 1828) | *Cir_fili* | D | | X |
| Polychaeta | *Cirriformia tentaculata* (Montagu, 1808) | *Cir_ten* | D | | X |
| Polychaeta | *Dodecaceria concharum* (Örsted, 1843) | *Dod_conc* | D | | X |
| Polychaeta | Capitellidae indet. (Grube, 1862) | *Cap_idae* | D | | X |
| Polychaeta | *Mastobranchus trinchesii* (Eisig, 1887) | *Mas_trin* | D | | X |
| Polychaeta | *Notomastus latericeus* (Sars, 1851) | *Not_late* | D | | X |

| | | | | | |
|---|---|---|---|---|---|
| Polychaeta | *Euclymene* sp. (Verrill, 1900) | *Euc_sp.* | D | | X |
| Polychaeta | *Armandia polyophthalma* (Kükenthal, 1887) | *Arm_poly* | D | X | X |
| Polychaeta | *Phyllodoce* sp. (Lamarck, 1818) | *Phy_sp.* | P | | X |
| Polychaeta | *Phyllodoce lineata* (Claparède, 1870) | *Phy_line* | P | | X |
| Polychaeta | *Syllis amica* (Quatrefages, 1866) | *Syl_ami* | P | | X |
| Polychaeta | *Syllis* sp. (Lamarck, 1818) | *Syl_*sp. | P | | X |
| Polychaeta | Syllidae indet. Grube, 1850 | *Syl_idae* | P | X | X |
| Polychaeta | *Ceratonereis (Composetia) costae* (Grube, 1840) | *Cer_cost* | P | | X |
| Polychaeta | *Alitta succinea* (Leuckart, 1847) | *Nea_succ* | D | | X |
| Polychaeta | *Nereis* sp. (Linnaeus, 1758) | *Ner_sp.* | P | X | X |
| Polychaeta | *Nereis rava* (Ehlers, 1864) | *Ner_rava* | P | | X |
| Polychaeta | *Nereis zonata* (Malmgren, 1867) | *Ner_zona* | P | | X |
| Polychaeta | *Perinereis cultrifera* (Grube, 1840) | *Per_cult* | G | X | X |
| Polychaeta | *Platynereis dumerilii* (Audouin & Milne Edwards, 1834) | *Pla_dume* | G | | X |
| Polychaeta | *Lysidice ninetta* Audouin & Milne-Edwards, 1833 | *Lys_nine* | P | | X |
| Polychaeta | *Nematonereis unicornis* (Grube, 1840) | *Nem_unic* | P | | X |
| Polychaeta | *Lumbrineris gracilis* (Ehlers, 1868) | *Lum_grac* | P | | X |
| Polychaeta | *Lumbrineris latreilli (*Audouin & Milne Edwards, 1834) | *Lum_latr* | P | | X |
| Polychaeta | *Lumbrineris tetraura* (Schmarda, 1861) | *Lum_tetr* | P | | X |
| Polychaeta | Dorvilleidae indet. (Chamberlin, 1919) | *Dor_idae* | P | | X |
| Polychaeta | *Owenia fusiformis* (Delle Chiaje, 1844) | *Owe_fus* | F | | X |
| Polychaeta | Terebellidae indet. (Malmgren, 1867) | *Ter_idae* | D | X | X |
| Polychaeta | *Amphitrite* sp. (O.F. Müller, 1771) | *Amp_sp.* | D | | X |
| Polychaeta | *Neoamphitrite edwardsi* (de Quatrefages, 1865) | *Amp_edwa* | D | | X |
| Polychaeta | *Amphitrite rubra* (Risso, 1826) | *Amp_rub* | D | | X |
| Polychaeta | *Amphitritides gracilis* (Grube, 1860) | *Amp_grac* | D | | X |
| Polychaeta | *Nicolea venustula* (Montagu, 1818) | *Nic_venu* | F | | X |
| Polychaeta | Sabellidae indet. (Latreille, 1825) | *Sal_idae* | F | X | X |
| Polychaeta | Serpulidae indet. (Rafinesque, 1815) | *Ser_idae* | F | | X |

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|---|---|---|---|---|---|
| Polychaeta | *Filograna* sp. (Berkeley, 1835) | *Fil_sp.* | F | | X |
| Polychaeta | *Serpula* sp. (Linnaeus, 1758) | *Ser_sp.* | F | | X |
| Polychaeta | *Vermiliopsis striaticeps* (Grube, 1862) | *Ver_stri* | F | | X |
| Polychaeta | *Neodexiospira pseudocorrugata* (Bush, 1905) | *Neo_pseu* | F | X | |
| Polychaeta | *Pileolaria militaris (*Claparède, 1870) | *Pil_mili* | F | X | X |
| Polychaeta | *Spirorbis* sp. (Daudin, 1800) | *Spi_sp.* | F | X | X |
| Arthropoda | *Chthamalus montagui* (Southward, 1976) | *Cht_mont* | F | X | X |
| Arthropoda | *Chthamalus stellatus* (Poli, 1795) | *Cht_stel* | F | X | X |
| Arthropoda | *Chthamalus* sp. (Poli, 1795) | *Cht_sp.* | F | X | X |
| Arthropoda | *Amphibalanus amphitrite* (Darwin, 1854) | *Bal_amph* | F | | X |
| Arthropoda | *Perforatus perforatus* (Bruguière, 1789) | *Bal_perf* | F | | X |
| Arthropoda | *Balanus trigonus* (Darwin, 1854) | *Bal_sp.* | F | | X |
| Arthropoda | *Balanus* sp. (Costa, 1778) | *Bal_trig* | F | | X |
| Arthropoda | *Athanas nitescens* (Leach, 1813 [in Leach, 1813-1814]) | *Ath_nite* | O | | X |
| Arthropoda | *Hippolyte* sp. (Leach, 1814 [in Leach, 1813-1814]) | *Hip_sp.* | O | | X |
| Arthropoda | *Eualus cranchii* (Leach, 1817 [in Leach, 1815-1875]) | *Tho_cran* | O | | X |
| Arthropoda | *Palaemon serratus* (Pennant, 1777) | *Pal_ser* | O | X | |
| Arthropoda | Dendrobranchiata indet. (Spence Bate, 1888) | *Nat_inde* | O | | X |
| Arthropoda | *Clibanarius erythropus* (Latreille, 1818) | *Cli_ery* | O | | X |
| Arthropoda | *Pisidia bluteli* (Risso, 1816) | *Pis_blut* | F | | X |
| Arthropoda | *Pisidia* sp.  (Leach, 1820) | *Pis_sp.* | F | | X |
| Arthropoda | *Porcellana platycheles* (Pennant, 1777) | *Por_pla* | O | | X |
| Arthropoda | *Processa* sp. (Leach, 1815 [in Leach, 1815-1875]) | *Pro_sp.* | P | X | |
| Arthropoda | *Xantho pilipes* (A. Milne-Edwards, 1867) | *Xan_pili* | G | X | X |
| Arthropoda | Mysida indet. (Haworth, 1825) | *Mys_inde* | O | X | X |
| Arthropoda | Cumacea indet. (Krøyer, 1846) | *Cum_inde* | O | | X |
| Arthropoda | *Zeuxo* sp. (Templeton, 1840) | *Zeu_sp.* | O | | X |
| Arthropoda | *Tanais dulongii* (Audouin, 1826) | *Tan_dul* | O | X | X |
| Arthropoda | *Leptochelia savigny* (Krøyer, 1842) | Lep_sav | O | X | X |
| Arthropoda | Tanaidacea indet. (Dana, 1849) | *Tan_inde* | O | | X |

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|---|---|---|---|---|---|
| Arthropoda | *Eurydice* sp. (Leach, 1815) | *Eur_sp.* | P | X | X |
| Arthropoda | *Gnathia dentata* (Sars G.O., 1872) | *Gna_dent* | P | | X |
| Arthropoda | *Gnathia vorax* (Lucas, 1849) | *Gna_vor* | Pa | | X |
| Arthropoda | *Gnathia* sp. (Leach, 1814) | *Gna_sp.* | P | | X |
| Arthropoda | Anthuroidea indet. (Leach, 1914) | Ant_idae | O | | X |
| Arthropoda | *Jaera (Jaera) nordmanni* (Rathke, 1837) | Jae_sp. | O | | X |
| Arthropoda | *Cymodoce* sp. (Leach, 1814) | *Cym_sp.* | G | | X |
| Arthropoda | *Sphaeroma* sp. (Latreille, 1802) | *Sph_sp.* | G | X | |
| Arthropoda | *Campecopea* sp. (Leach, 1814) | Cam_sp. | G | X | |
| Arthropoda | *Dynamene edwardsi* (Lucas, 1849) | *Dyn_edwa* | G | X | X |
| Arthropoda | *Dynamene torelliae* (Holdich, 1968) | *Dyn_tore* | G | | X |
| Arthropoda | Bopyridae indet. (Rafinesque, 1815) | Bop_idae | P | | X |
| Arthropoda | Amphipoda indet. (Latreille, 1816) | Amp_inde | O | X | X |
| Arthropoda | Pycnogonidae indet. (Wilson, 1878) | *Pyc_inde* | O | | X |
| Bryozoa | *Conopeum seurati* (Canu, 1928) | *Con_seur* | F | | X |
| Bryozoa | *Cryptosula pallasiana* (Moll, 1803) | *Cry_pall* | F | | X |
| Bryozoa | *Schizoporella errata* (Waters, 1878) | *Sch_erra* | F | | X |
| Echinodermata | Asteroidea indet. (juv.) (de Blainville, 1830) | *Ast_idea* | P | | X |
| Echinodermata | *Amphiura chiajei* (Forbes, 1843) | *Amp_chia* | O | | X |
| Echinodermata | *Amphipholis squamata* (Delle Chiaje, 1828) | *Amp_squa* | O | | X |
| Echinodermata | *Amphiura* sp. (Forbes, 1843) | *Amp_sp.* | O | | X |
| Echinodermata | Ophiuroidea indet. (Gray, 1840) | *Oph_idea* | O | | X |
| Echinodermata | *Asterina gibbosa* (Pennant, 1777) | *Ast_gibb* | P | X | |

*Table A2. List of macroalgae found in upper and lower mediolittoral*

| Phylum | Algae | Upper subbelt | Lower subbelt |
|---|---|---|---|
| Cyanobacteria | *Microcoleus vaginatus* (Vaucher) Gomont ex Gomont, 1892 | X | X |
| Cyanobacteria | *Rivularia atra* Roth ex Bornet & Flahault, 1886 | X | |
| Chlorophyta | *Chaetomorpha* sp. Kützing, 1845 | | X |
| Chlorophyta | *Cladophora* spp. Kützing, 1843 | | X |
| Chlorophyta | *Ulothrix* sp. Kützing, 1833 | X | X |
| Chlorophyta | *Ulva intestinalis* Linnaeus, 1753 | X | X |
| Chlorophyta | *Ulva* sp. Linnaeus, 1753 | X | X |
| Rhodophyta | *Corallina officinalis* Linnaeus, 1758 | | X |
| Rhodophyta | *Jania* sp. J.V.Lamouroux, 1812 | | X |
| Rhodophyta | *Lithophyllum* spp. Philippi, 1837 | X | X |
| Rhodophyta | *Ceramium* spp. Roth, 1797 | X | X |
| Rhodophyta | *Chondria* spp. C.Agardh, 1817 | | X |
| Rhodophyta | *Gelidium* sp. J.V.Lamouroux, 1813 | X | X |
| Rhodophyta | *Gelidium pusillum* (Stackhouse) Le Jolis, 1863 | | X |
| Rhodophyta | *Chondracanthus acicularis* (Roth) Fredericq, 1993 | X | X |
| Rhodophyta | *Laurencia* spp. J.V.Lamouroux, 1813 | X | X |
| Rhodophyta | *Polysiphonia* sp. Greville, 1823 | X | X |
| Rhodophyta | *Pterocladiella capillacea* (S.G.Gmelin) Santelices & Hommersand, 1997 | | X |
| Ochrophyta | *Colpomenia* sp. (Endlicher) Derbès & Solier, 1851 | X | X |
| Ochrophyta | *Cystoseira compressa* (Esper) Gerloff & Nizamuddin, 1975 | | X |
| Ochrophyta | *Dictyota dichotoma* (Hudson) J.V.Lamouroux, 1809 | | X |
| Ochrophyta | *Ectocarpus* sp. Lyngbye, 1819 | | X |
| Ochrophyta | *Fucus virsoides* J.Agardh, 1868 | X | X |
| Ochrophyta | *Padina pavonica* (Linnaeus) Thivy, 1960 | | X |
| Ochrophyta | *Ralfsia verrucosa* (Areschoug) Areschoug, 1845 | | X |
| Ochrophyta | *Sphacelaria* spp. Lyngbye, 1818 | | X |
| Ochrophyta | *Stypocaulon scoparium* (Linnaeus) Kützing, 1843 | | X |

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