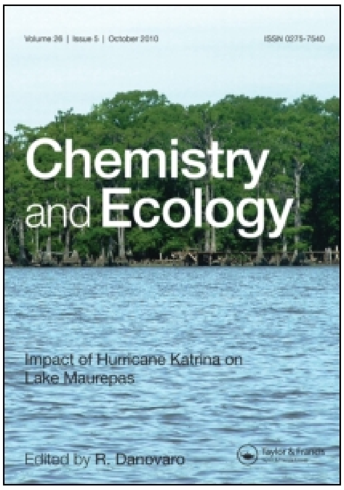

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MAPPING OF THE BENTHIC COMMUNITIES IN THE TARANTO SEAS USING SIDE-SCAN SONAR AND AN UNDERWATER VIDEO CAMERA

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Side-scan sonar and underwater video camera records as well as dredging samples were used to map the bottom morphology and biocoenoses in the Taranto seas. A 1:20,000 scale chart has been produced with all the data recorded. Most of the study area consists of biocoenoses affected by the anthropogenic activities of the town of Taranto. Some native broadly tolerant species seem to benefit from these activities and become increasingly dominant. Environmental modifications also seem to favour the settlement of exotic species.

Keywords: Benthic communities; Mapping; Side-scan sonar; Underwater video camera; Taranto seas; Ionian sea

1 INTRODUCTION

The study of the morphology and bionomic characteristics of the sea bottoms on a large scale is very important in maintaining the inshore coast (Virno Lamberti *et al.*, 1998). Although traditional sampling of the composition of the substrata and the benthic habitats with dredge, grab and scuba is direct and more accurate, it is very time-consuming. Other sampling methods, such as side-scan sonar and underwater video, can reduce the amount of time needed to cover broad surfaces. These methodologies can provide information about the distribution of the biocoenoses characterized by particular and abundant species. Moreover, bottom videotape-recording can be easily elaborated to produce benthic maps (Ardizzone, 1992; Norris *et al.*, 1997; McRea *et al.*, 1999). Benthic cartography meets various scientific and management needs, providing useful information on the bottom conditions and biocoenoses distribution as well as increasing the ease and efficacy of the interpretation and comparison on both a spatial and temporal scale (Bianchi *et al.*, 1995; Tunesi *et al.*, 2002). This is even more important where anthropogenic activities produce changes in environmental parameters affecting the marine ecosystem structure.

The Taranto seas (southern Italy, Ionian Sea) represent a typical situation in which the marine ecosystem is subject to different anthropogenic activities such as sewage output, industrial

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activities, intense naval traffic and mussel breeding. Although, in the last 30 years, several studies have been carried out on the benthic communities in the Taranto seas (Parenzan 1969, 1983; Tursi *et al.*, 1978, 1980, 1981; Chieppa and Tursi, 1980; Panetta, 1980, 1981; Cecere *et al.*, 1989, 1991, 1992, 1996; Scardi *et al.*, 1997; Costantino *et al.*, 1999), the only available map of their biocoenoses dates back to the work of Parenzan (1969, 1983).

The SPICAMAR project (Pilot Study for the Environmental Characterization of "at risk" Marine Areas), financed by the Ministry of University and Scientific Research, in 2000–2003 was conducted in the Taranto seas to evaluate the condition of the marine ecosystem and benthic habitats subject to several human activities. In the first phase of this project, a side-scan sonar and an underwater video camera were used to:

(1) quantify preliminarily the extension of the biocoenoses distributed in the study area;
(2) identify sites and zones to carry out biological samplings with dredge, grab and scuba to better identify the biocoenoses and sediment type;
(3) produce a benthic map of the study area.

The aim of this paper is to provide a preliminary benthic map of the study area using side-scan sonar and underwater video camera records validated by means of species composition data from the samples collected by dredging. Quantitative data from grab and scuba related to both benthic species and sediment type are being analysed and will constitute the content of a more comprehensive paper.

2 MATERIAL AND METHODS

2.1 Study Area

The town of Taranto is located on the coast of the north-western Ionian Sea (eastern-central Mediterranean). It overlooks the open sea to the south-west in the Mar Grande basin and the basin of Mar Piccolo, which comprises two smaller inlets (I and II Seno), to the north-east. The study area regards the two inlets of the Mar Piccolo, the Mar Grande basin and the marine area westwards outside the Mar Grande (Fig. 1).

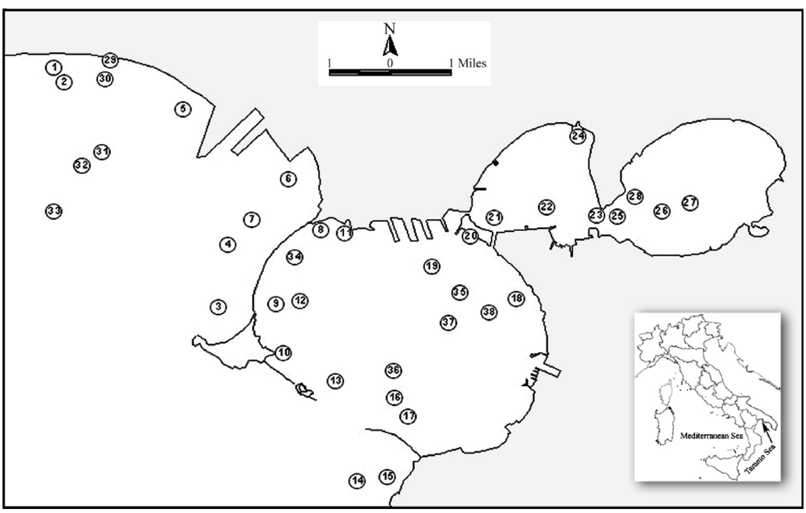

FIGURE 1 Map of the study area with dredge sampling stations.

The Mar Piccolo covers an area of 20.72 km^2. Its maximum depth is 13 m in the first inlet (I Seno) and 9 m in the second (II Seno) (Scardi *et al.*, 1997). The Mar Piccolo basin is connected to the Mar Grande through two small channels. The Mar Grande basin covers an area of 35.5 km^2. It is an oval bay with the main axes north–south and east–west 5300 and 7800 m long, respectively. Its maximum depth is 42 m. The Mar Grande is limited southward by the Cheradi Islands (San Pietro and San Paolo). The central part of Mar Grande is known as the "Canalone", which is about 1300 m wide and 40 m deep.

The Taranto seas are subject to several anthropogenic impacts, including urban and industrial sewage outputs, intense naval traffic and widespread mussel-breeding activity. The urban sewage plants are located around the two inlets of Mar Piccolo, on the eastern coast of the Mar Grande (in front of Taranto city) and outside the Mar Grande, while the industrial sewage is concentrated in the northern Mar Grande and outside the basin westwards along the industrial piers. The intense naval traffic is due to the presence of the Italian Navy Base, in the first inlet of the Mar Piccolo, and to intercontinental industrial and merchant shipping regarding mostly the two industrial loading wharfs in the northern Mar Grande and at the roadstead of this basin. Mussel breeding farms are present in a great part of the Mar Piccolo basin and in the south-eastern area of the Mar Grande. Because of all these anthropogenic impacts, the Ministry of the Environment has classified this area as an "area at high risk of environmental crisis".

2.2 Sampling and Data Processing

The side-scan sonar records were taken on about 100 linear transects with a depth of 3–50 m. Two different side-scan sonar coverage ranges were used in relation to the surveyed zones (free from military and harbour structures and breeding systems) in the study area. In particular, a coverage range of 250 m was adopted in the open sea and on the north-west side of the Mar Grande and of 125 m in the remaining parts of the Mar Grande and in the two inlets of the Mar Piccolo (July 2001).

The side-scan sonar marks were identified for the whole area and then used to plan the underwater video recording. The equipment was connected through a cable to a support craft and towed along the transects. Underwater video camera images were displayed on a TV monitor and recorded on videotape. The vessel speed and position were measured using GPS. The whole area was covered by 12 h of videotape records. Qualitative samples were collected on sandy and muddy bottoms by dredging (38 stations) to confirm the type of biocoenosis preliminarily identified with the underwater video camera (July 2001). The sampled benthic fauna was sorted and identified to species level for the following taxonomic groups: molluscs, annelids, crustaceans, echinoderms and tunicates. A matrix of the presence–absence data per species station was compiled. A cluster analysis was performed using the Bray–Curtis similarity coefficient and group average method using the PRIMER 5 package (Clarke and Warwick, 2001). An analysis of similarities (ANOSIM) was performed to test the differences between the groups of the species station. Finally, the SIMPER routine was carried out to characterize by species each faunal association and to establish which species contribute to the measures of similarity/dissimilarity between individual samples or sample groups.

Thanks to the integrated analysis of the marks taken with the side-scan sonar and the high quality of the video images validated by dredging data as well as multivariate analysis, a map of the different kind of substrata with the evident biocoenoses of the Taranto seas (*sensu* Meinesz *et al.*, 1983, modified by Tunesi *et al.*, 2002) has been produced (Bianchi *et al.*, 2003).

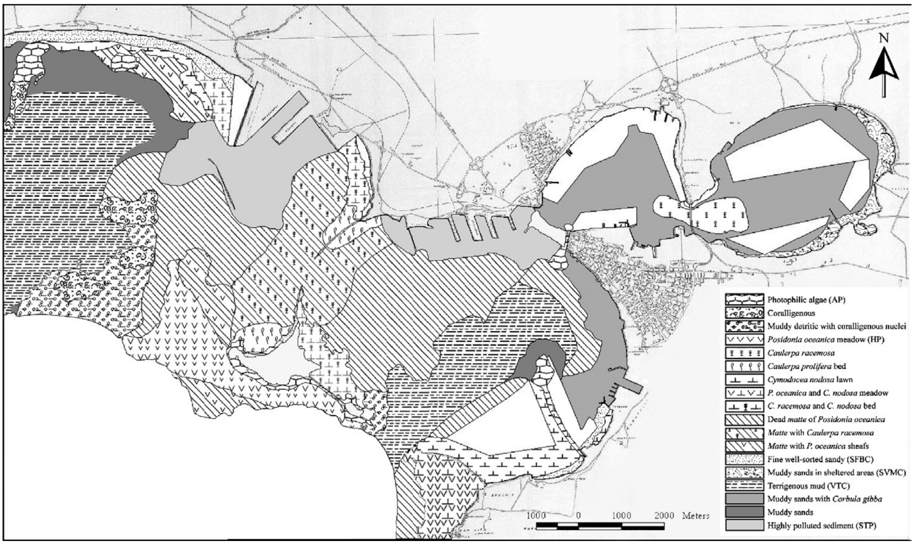

FIGURE 2 Map of the benthic communities in the Taranto seas.

3 RESULTS

3.1 Side-Scan Sonar Marks and Underwater Video Camera Images

The benthic communities of the Taranto seas with a surface area of about 102 km^2 have been mapped (Fig. 2).

The side-scan sonar marks indicate that the hard substrata covers a restricted area along the coast of the study area (about 4% of the total area) (Tab. I). In particular, there are hard substrata in the canal between the Mar Grande and the first inlet of the Mar Piccolo, in some

TABLE I Biocoenoses of the Taranto seas, surface area covered (km^2) and their percentage (%) of the total study area.

Biocoenosis	*km^2*	%
Terrigenous mud (VTC)	19.324	18.84
Dead *matte* of *P. oceanica*	19.002	18.52
Muddy sands with *Corbula gibba*	12.677	12.36
Highly polluted sediment (STP)	8.914	8.69
Dead *matte* with *Caulerpa racemosa*	7.480	7.29
Posidonia oceanica meadows (HP)	4.624	4.51
Muddy sands	4.265	4.16
Matte with *P. oceanica* sheaves	3.796	3.70
Muddy detritic bottom with coralligenous nuclei	3.658	3.57
Cymodocea nodosa lawn	3.396	3.31
C. racemosa and *C. nodosa* bed	2.824	2.75
Photophilic algae (AP)	2.406	2.35
P. oceanica and *C. nodosa* meadow	2.161	2.11
Coralligenous (C)	1.920	1.87
Fine, well-sorted sand (SFBC)	1.811	1.77
Muddy sands in sheltered areas (SVMC)	1.765	1.72
Caulerpa prolifera bed	1.295	1.26
Caulerpa racemosa bed	1.270	1.24
Total mapped area	102.5854	

shallow areas of the Mar Grande roadstead and outside this basin westwards as well as around the Cheradi Islands. The soft substrata cover most of the study area (96% of the total). A total of 194 species were collected on these bottoms: 79 molluscs, 37 annelids, 37 crustaceans, 24 echinoderms and 14 tunicates.

The biocoenosis of the terrigenous mud (VTC) is the most widespread in the study area (about 20 km^2, 19% of the mapped area), followed by dead *Posidonia mattes* (about 19 km^2, 18.5% of the mapped area), and the muddy-sand bottom with the bivalves *Corbula gibba* (about 13 km^2, 12% of the mapped area), together constituting about 50% of the mapped area.

The terrigenous mud biocoenosis is distributed in the middle of the Mar Grande and in a wide area off the Patemisco river; the dead *Posidonia mattes* extend over a large area of the Mar Grande and around the *Posidonia* meadow off Mar Grande; the muddy-sand bottom with *Corbula gibba* is widespread in the two inlets of the Mar Piccolo and barely out of this basin.

Furthermore, the two inlets of the Mar Piccolo are characterized by reduced dark muddy bottoms covered by drift algal species such as *Chaetomorpha linum*, *Cladophora hutchinsiae* and *Ulva* sp. The molluscs *Corbula gibba*, the exotic species *Musculista senhousia* (Asian date mussel), the sedentary annelid *Branchiomma luctuosum* (lessepsian species) and the ascidians *Phallusia mamillata*, *Ascidiella aspersa* and *Botryllus* sp. represent the main components of the macrofauna.

A wide bed of *Caulerpa racemosa* was observed between the first and second inlet. The Mar Grande basin appears to be characterized, on the north-eastern side, by polluted dark mud, mostly due to the sewage output of the town. This area is abundantly colonized by *B. luctuosum*. The bottoms of the "Canalone" are characterized by a terrigenous mud with an evident *facies* of the gastropods *Turritella communis* extending down to a depth of 20 m. The north-western areas, outside the Mar Grande, close to the industrial wharfs, are covered by polluted mud on which *C. racemosa* patches are shown. The south-eastern side, where the mussel-breeding systems are located, is characterized by sparse *Cymodocea nodosa* beds. *Posidonia oceanica* meadows are only distributed in areas off the Cheradi Islands and off Cape San Vito. Most of the remaining Mar Grande basin consists of a large area characterized by dead *Posidonia mattes* covered with mud. The north-west side of this latter area is covered by *C. racemosa.*

The area located north-westwards is almost completely characterized by sandy bottoms. In particular, along the coast, there are fine, well-sorted sands down to 4 m in depth. Beyond these bottoms, patches of *C. nodosa* are distributed between 3 and 6 m. Biocoenosis of photophilic algae and *mattes* with few living sheaves of *P. oceanica* are spread between 5 and 10 m in depth. Offshore, there is a wide sand-muddy area with the presence of clay and a broad area of terrigenous muds.

3.2 Multivariate Analysis

The resulting dendrogram of the species-station matrix indicates the presence of four main clusters (Fig. 3). The first cluster (I) regards VTC biocoenosis *sensu* Pérès and Picard (1964) in the Mar Grande; the second (II) concerns the muddy-sandy bottom with *Corbula gibba* of the Mar Piccolo; the third (III) relates to the dead *Posidonia mattes*; and the fourth regards the faunal assemblage found in *C. nodosa* sea-grass substrate. The ANOSIM test confirmed that the four species-station groups were significantly different with a global $R = 0.767$ ($P < 0.01$). The first group showed an average similarity of 22.15% and was characterized by limicolous species such as the gastropod *Turritella communis* and the annelids *Glycera tridactyla* and *Laetmonice hystrix* (Tab. II). The second group presented an

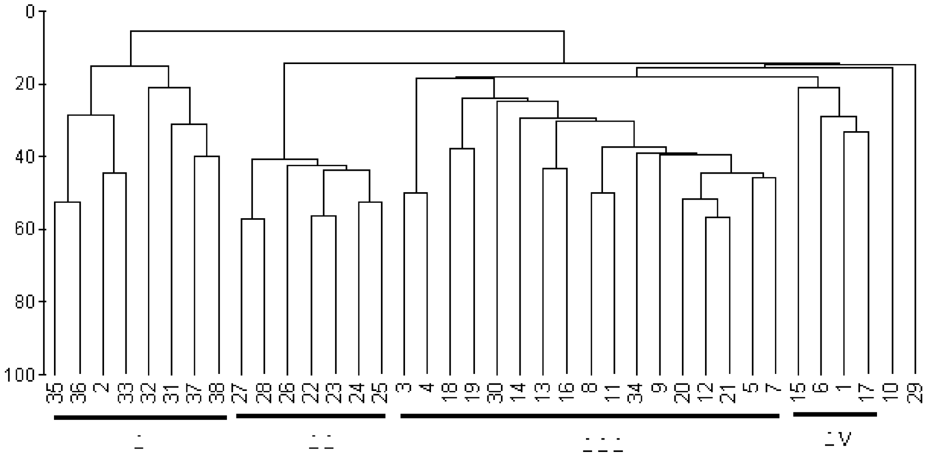

FIGURE 3 Dendrogram of 38 dredge stations in the Taranto seas during July 2001.

TABLE II Average similarity in each group identified by cluster analysis with indication of each species' contribution (Sp. %) and cumulative contribution (Cum %).

	Sp. %	*Cum.* %
Group I		
Average similarity: 22.15		
Turritella communis Risso, 1826	65.58	65.58
Glycera tridactyla Schmarda, 1861	14.52	80.10
Laetmonice hystrix Savigny, 1820	3.58	83.68
Amphiura chiajei Forbes, 1843	2.69	86.37
Antalis inaequicostatum Dautzenberg, 1891	2.48	88.85
Lumbrineris latreilli Audouin & Milne-Edwards, 1834	2.30	91.15
Group II		
Average similarity: 43.59		
Eunice vittata (Delle Chiaje, 1828)	12.68	12.68
Paphia aurea (Gmelin, 1791)	9.03	21.71
Ascidiella aspersa (Müller, 1776)	8.65	30.36
Musculista senhousia (Benson in Cantor, 1842)	8.65	39.02
Branchiomma luctuosum Grube, 1869	8.55	47.57
Corbula gibba (Olivi, 1792)	6.59	54.15
Orbinia latreillii (Audouin & Milne-Edwards, 1833)	5.41	59.57
Modiolus barbatus (Linnè, 1758)	5.41	64.98
Chlamys glabra (Linnè, 1758)	5.34	70.32
Mytilus galloprovincialis Lamarck, 1819	3.19	73.51
Pectinaria koreni (Malmgren, 1866)	3.13	76.64
Tricolia tenuis (Michaud, 1829)	1.86	78.51
Neanthes caudata (Delle Chiaje, 1828)	1.82	80.33
Pista cristata (O.F. Müller, 1776)	1.77	82.10
Notomastus latericeus M. Sars, 1851	1.65	83.74
Glycera tridactyla Schmarda, 1861	1.65	85.39
Haminoea navicula (Da Costa, 1778)	1.65	87.03
Megalomma vesiculosum (Montagu,1815)	1.59	88.63
Nassarius reticolatus (Linnè, 1758)	1.36	89.99
Acanthocardia paucicostata (Sowerby G.B.II, 1841)	1.36	91.35

(*continued*)

TABLE II Continued

	Sp. %	*Cum.* %
Group III		
Average similarity: 29.12		
Pitar rudis (Poli, 1795)	10.53	10.53
Gouldia minima (Montagu, 1803)	10.15	20.68
Nucula nucleus (Linnè, 1758)	7.44	28.12
Psammechinus microtuberculatus (Blainville, 1825)	6.37	34.49
Laetmonice hystrix Savigny, 1820	6.01	40.50
Venericardia antiquata (Linnè, 1758)	3.74	44.24
Plagiocardium papillosum (Poli, 1795)	3.36	47.60
Microcosmus exasperatus Heller, 1878	3.08	50.68
Paracentrotus lividus (Lamarck, 1816)	3.03	53.71
Modiolus barbatus (Linnè, 1758)	3.03	56.74
Paphia aurea (Gmelin, 1791)	2.83	59.57
Cerithium vulgatum Bruguière, 1792	2.65	62.22
Corbula gibba (Olivi, 1792)	2.52	64.74
Chlamys glabra (Linnè, 1758)	2.51	67.25
Antalis inaequicostatum Dautzenberg, 1891	2.44	69.69
Ocnus planci (Panning, 1962)	2.36	72.05
Macropipus arcuatus (Leach, 1814)	2.11	74.16
Glycera tridactyla Schmarda, 1861	2.06	76.22
Hexaplex trunculus (Linnè, 1758)	2.04	78.26
Parthenope massena (Roux, 1830)	1.82	80.08
Maja squinado (Herbst, 1788)	1.38	81.46
Pista cristata (O.F. Müller, 1776)	1.24	82.70
Ilia nucleus (Linnaeus, 1758)	0.99	83.69
Chlamys varia (Linnè, 1758)	0.89	84.58
Holothuria tubulosa Gmelin, 1788	0.87	85.45
Chiton olivaceus Spengler, 1797	0.83	86.28
Monodaeus couchi (Couch, 1851)	0.83	87.11
Liocarcinus depurator (Linnaeus, 1758)	0.80	87.91
Gibbula magus (Linnè, 1758)	0.75	88.66
Amphiura chiajei Forbes, 1843	0.64	89.30
Venus verrucosa Linnè, 1758	0.64	89.94
Ascidiella aspersa (Müller, 1776)	0.62	90.56
Group IV		
Average similarity: 25.82		
Holothuria tubulosa Gmelin, 1788	26.30	26.30
Hexaplex trunculus (Linnè, 1758)	26.30	52.60
Laetmonice hystrix Savigny, 1820	13.22	65.82
Cerithium vulgatum Bruguière, 1792	12.63	78.45
Asterina gibbosa (Pennant, 1777)	4.61	83.06
Psammechinus microtuberculatus (Blainville, 1825)	4.30	87.36
Parthenope angulifrons Latreille, 1825	4.30	91.66

average similarity of 43.59% and was characterized by a species pool with a high adaptation capacity (e.g. *Eunice vittata*, *Paphia aurea*, *Ascidiella aspersa*, *Musculista senhousia* and *Notomastus latericeus*) and species that live in eutrophic sites, such as the bivalves *Corbula gibba* and the annelid *Branchiomma luctuosum*. The third group showed an average similarity of 29.12% and was characterized by opportunistic species, such as the annelid *Glycera tridactyla* and the molluscs *Paphia aurea*, species of the detritic bottom, such as the mollusc *Pitar rudis*, as well as limicolous species, such as the annelids *L. hystrix* and *Pista cristata* and the molluscs *Antalis inaequicostatum* and *Nucula nucleus*. Species of the phanerophyte sea-grass, such as the bivalves *Modiolus barbatus* and *Venus verrucosa*, were also found in some stations of the third cluster. Finally, the fourth group showed an average similarity of 25.82% and was mostly characterized by species with a wide ecological distribution, such as the sea cucumber *Holoturia tubulosa*, the molluscs *Hexaplex trunculus* and *Cerithium vulgatum*, and the annelid *Laetmonice hystrix*.

4 DISCUSSION AND CONCLUSIONS

The side-scan sonar and underwater video camera survey, integrated with spot qualitative samples, has provided information on the characteristics of the sea bottoms on a large scale and in a short time. Moreover, this integrated method appears to be useful for planning further detailed qualitative and quantitative surveys according to a traditional approach using dredges, grabs and dives (Ardizzone, 1992; Bianchi *et al.*, 2003).

The benthic communities observed in the Taranto seas are severely affected by the anthropogenic activities of the town, including the mussel-breeding systems in the Mar Piccolo and the industrial and shipping activities in the Mar Grande. In fact, the *C. nodosa* meadows indicated by Parenzan (1969, 1983) have completely disappeared, and the bottoms of the two inlets in the Mar Piccolo are completely covered by reduced mud. In the first inlet, which is deeper, the dominance (although not quantified) of some opportunistic species was shown, while in the second, the occurrence of nitrophilic algal species, such as a drift algal felt, represents the main characteristic of the bottoms. Many species recorded in the past (Tursi *et al.*, 1974, 1981; Panetta, 1977, 1980, 1981) seem to have completely disappeared (*Donax variegatus*, *Pseudamussium clavatum*, *Conus mediterraneus*, *Dosinia lupinus*, *Lucinella divaricata*, *Nuculana pella*, etc.), whereas others are rarely found (*Modiolus barbatus*, *Lima tuberculata*, *Plagiocardium papillosum*, *Pitar rudis*, *Venus verrucosa*, etc.). The most abundant species found in this study are those with wide ecological requirements, such as *Corbula gibba*, *Paphia aurea* and *Hexaplex trunculus*, indicating a marked level of instability (Bellan *et al.*, 1985).

The mud deposition phenomenon due to the industrial and urban sewage output is also remarkable in the Mar Grande basin. The large area with *P. oceanica* meadows mapped by Parenzan (1969) is now characterized by dead muddy *mattes* colonized by *C. racemosa*. Moreover, this algal species has been found in an area where Parenzan (1969) indicated the presence of mixed meadows of *C. nodosa* and *Caulerpa prolifera*. This particular *facies* is still present only on the bottoms west of San Pietro Island outside the Mar Grande. The greater number of species found on the dead *Posidonia mattes* is most likely due to the diversified nature of the substrate in which the characteristics of both sandy-muddy bottoms and bottoms with a thick weft of rhizomes coexist (Gray, 1974; De Metrio *et al.*, 1980; Bello *et al.*, 1982). A narrow meadow of *P. oceanica*, bordered by a large area covered by dead muddy *mattes*, is still present off the Cheradi Islands.

Outside the Mar Grande, northwest of the Patemisco River, the occurrence of sandy bottoms was reported by Bedulli *et al.* (1986). The presence of clay is probably due to the dredging work on the area around the industrial docks.

From all the above, it is evident that some biocoenoses, such as the sea grass of *P. oceanica* and the photophilic seaweed bottoms, have disappeared in most of the surveyed zones because of the polluted condition of the Taranto seas. Indeed, the industrial and urban sewage outputs introduce continuous instability for the bottoms, preventing the settlement of well-structured biocoenoses and favouring only those species with a wide ecological tolerance, as observed in other areas (Nicolaidou *et al.*, 1989; Currie and Parry, 1999; Leppäkoski *et al.*, 1999), suggesting retrogression to dominance by opportunistic species (Gray, 1989). Furthermore, the anthropogenic stress and the wide distribution of the muddy bottoms have most likely favoured the settlement of exotic opportunistic species (Galil, 2000; Occhipinti

Ambrogi, 2000; Mistri, 2003). In this regard, the Asian date mussel *M. senhousia* has recently been recorded in the area, with a self-perpetuating population (Mastrototaro *et al.*, 2003), whereas *C. gibba*, which is an endemic species, has become dominant in the Mar Piccolo and has been recorded as an exotic species as far away as Australia (Currie and Parry, 1999). These widespread, broadly tolerant species contribute to the "biotic homogenization process" on a global scale (McKinney and Lockwood, 1999).

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