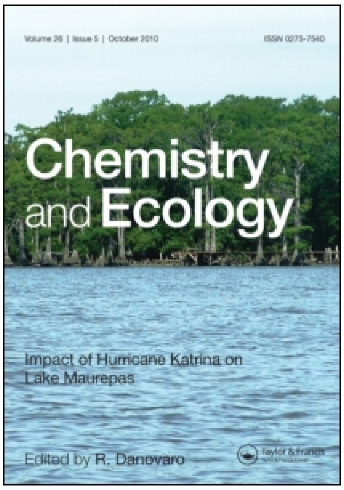

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MEIOBENTHIC BIODIVERSITY IN AREAS OF THE GULF OF TARANTO (ITALY) EXPOSED TO HIGH ENVIRONMENTAL IMPACT

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Biological and chemical parameters (meiofauna density and diversity, redox profiles) were investigated in relation to the environmental conditions of sediments in the Gulf of Taranto. Sediment cores were collected from 42 stations from −5 to −20 m depth, in 1995, 2000 and 2001. Meiofauna abundance and diversity were significantly lower in the Mar Piccolo, the area most heavily polluted by organic loads; in Mar Grande and Chiatona areas the same parameters showed slightly higher values. Eh profiles revealed anoxic conditions in coastal sediments impacted by industrial and sewage discharges. Meiofauna density ranged from 186 to 1370 individuals $\times$ 10 cm^{-2}. Generally, over 80% of total meiofauna was composed of nematodes; the contribution of other taxa is much less important. The widespread presence of the lessepsian Chlorophyte *Caulerpa racemosa* since 1996, seemed to enhance the abundance of meiofauna, and increased microhabitat complexity, but reduced diversity of some taxa, such as the meiobenthic crustaceans. Comparing 2001–2002 data with 1995 (before *C. racemosa* invasion), the recent decrease of some groups (ostracods, amphipods, isopods, tanaids and cumaceans) was markedly evident. In conclusion, our findings confirm the chronically degraded environmental conditions in the Gulf of Taranto, and draw attention to the further contribution of *C. racemosa* invasion.

Keywords: Meiofauna; Pollution; *Caulerpa racemosa*; Gulf of Taranto

1 INTRODUCTION

For decades, the Gulf of Taranto has been exposed to severe and heterogeneous environmental stress (*e.g.* Cardellicchio *et al.*, 1991). The ancient part of the city of Taranto is placed on a small isle dividing the sea inlet (Mar Grande) from the inner lagoon (Mar Piccolo). Industrial and harbour activities that directly release waste material in the Mar Grande, and the spilling of huge quantities of urban and agriculture sewage into the Mar Piccolo and Chiatona sea bottoms, pose a serious risk to both ecosystems and humans. Furthermore, since 1996, the lessepsian seaweed *Caulerpa racemosa* (Chlorophyta) has widely invaded the whole area, particularly sandy bottoms and *Posidonia oceanica* 'matte morte' in the industrial zone, and in the less compromised subtidal area of the Cheradi Islands (Buia *et al.*, 1998). This invasive macroalgal species shows a broad tolerance to different environmental conditions

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and its extreme efficiency of dispersal, mostly due to the high rates of sexual and asexual reproduction (Panayotidis and Zuljevic, 2001), could be responsible for drastic changes in soft-bottom macrofaunal communities (Argyrou *et al.*, 1999).

The only available published data on the structure of meiobenthic communities in sediments colonized by allochthonous seaweed species examined the congeneric species *Caulerpa taxifolia* (Poizat and Boudouresque, 1996). Therefore, the present investigation represents the first attempt at evaluating the changes in the structure and diversity of meiofauna related to a new biotic disturbance factor (*C. racemosa* invasion).

More generally, we report the present status of the meiobenthic communities of the Gulf of Taranto, an area chronically exposed to multi-sources pollution (urban, agricultural, industrial and biological impact).

2 MATERIALS AND METHODS

Sediment samples were obtained in June 2001 (24 sampling sites) and in July 2002 (11 sampling sites) in the Gulf of Taranto (Mar Piccolo, Mar Grande, Chiatona/Industrial area). The results are here compared to additional data previously collected from seven sampling sites located in the same areas (Mar Grande and Mar Piccolo excluded) in June 1995. The total number of sediment sampling sites investigated in the present study is 42 (Fig. 1). The choice of the 2001–2002 stations in Chiatona/Industrial area was made on the basis of the 1995 stations allocation. The sampling stations in Mar Grande and Mar Piccolo (2001–2002) were randomly allocated.

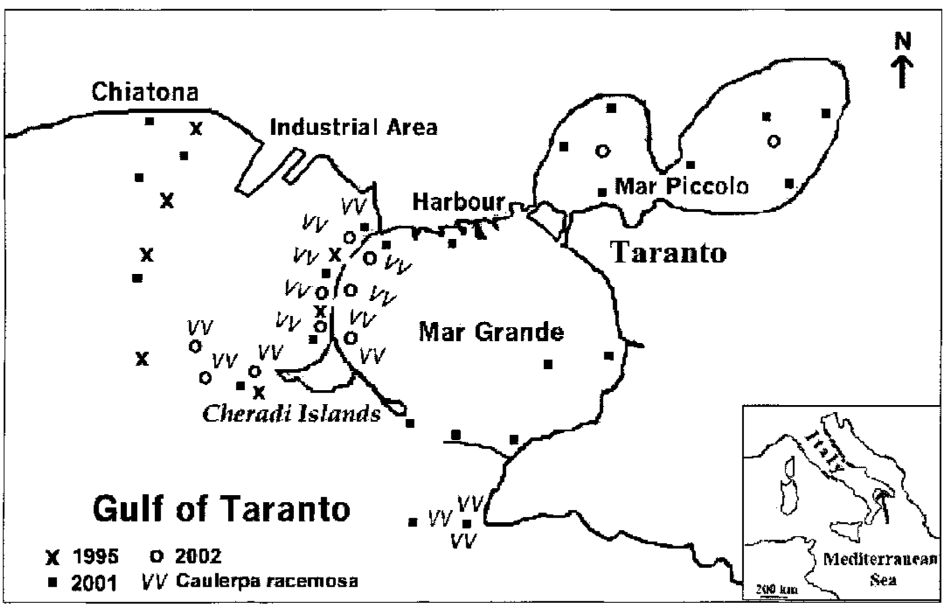

FIGURE 1 Study area with 42 sampling sites (X, 1995; ■, 2001; ○, 2002; *VV* areas with *C. racemosa* are reported).

Sediments were collected by means of a Van Veen grab from depths ranging between 5 and 20 m. Subsamples were obtained manually using perspex corers (three replicates from each site; 2.8 cm internal diameter) down to 5 cm sediment depth. Meiofauna were first anaesthetized ($MgCl_2$ in seawater), then preserved with 5% formalin–seawater, and finally extracted from the sediment using a 45 μm mesh size sieve. The individuals were sorted and enumerated in stereomicroscopy and identified using compound microscopy.

Sediment redox (Eh) profiles were obtained for each of the grab samples. The Eh values were measured using a naked-platinum tip Eh-electrode (HI 3131B, Hanna Instruments) connected to a portable pH–Eh-meter (HI 8424, Hanna Instruments). The electrode was inserted into the sediment at 1 cm intervals, to a depth of 8–10 cm in the sediment.

3 RESULTS

Data resulting from 1995, 2001 and 2002 surveys are summarized in Table I. Average meiofauna densities were generally very low, ranging from 186 ± 53 (2001, Mar Piccolo) to 1370 ± 223 individuals $10\,cm^{-2}$ (2001, Mar Grande). Shannon Diversity (H′) and Evenness (J) indices showed on average higher values in 1995 (1.7 and 0.6, respectively), than in 2001–2002, often lower than 1.5 (for H′) and 0.5 (for J).

Eh profiles revealed negative values below the upper layers of sediments at almost all sampling stations, indicating markedly anoxic conditions of the whole study area (Fig. 2). The lowest redox conditions were recorded in Mar Piccolo, with −145 mV already at 1 cm depth.

In 2001–2002, 70% of total meiofauna collected in Mar Grande and Chiatona was composed of nematodes; the contribution of other meiobenthic groups like crustaceans, annelids and turbellarians was much less important (Fig. 3). In Mar Piccolo, at all sampling sites, the number of groups is very low, with nematodes representing about 90% of total meiofauna. A distinctly higher degree of diversity was evident in 1995: 14 major taxa were identified and a lower abundance of nematodes was observed.

The effects of the recent invasion of *C. racemosa* in the Gulf of Taranto seemed to be relevant to the average density of meiofauna values and mostly to the assemblage structure of meiobenthic crustaceans. Comparing 1995 data (before the invasion occurred) with 2001–2002, the decrease of groups more sensitive to stressed conditions was evident. In 2001–2002, the abundances of ostracods, amphipods, isopods, tanaids and cumaceans

TABLE I Meiofaunal data resulting from 1995, 2001 and 2002 surveys.

	1995 MG–C	*2001 MG–C*	*2001 MP*	*2002 MG–C*	*2002 MP*
Total sampling stations	7	17	7	9	2
Meiobenthos average density ± SD (individuals $10\,cm^{-2}$)	1146 ± 337	1370 ± 223	276 ± 61	600 ± 109	186 ± 53
Shannon–Wiener diversity (H′)	1.7	1.2	0.5	1.4	1.3
Pielou Evenness (J)	0.6	0.4	0.3	0.5	0.6
Average number of taxa per station	14	7	4	8	5

Note: MG–C = Mar Grande/Chiatona areas; MP = Mar Piccolo basin.

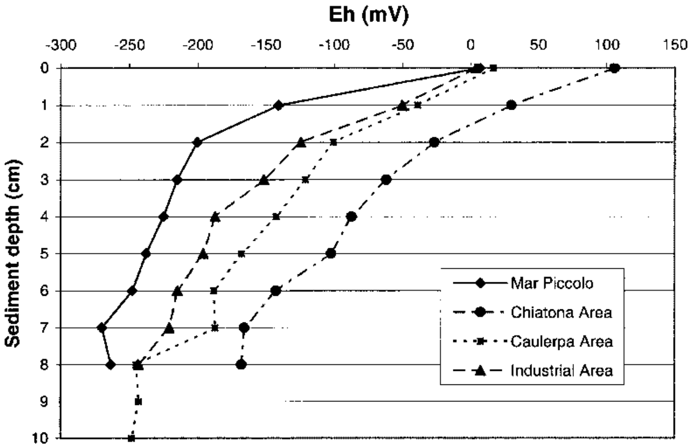

FIGURE 2 Sediment Redox profiles (Eh) in selected stations of the study area.

were much lower relative to epi-endobenthic harpacticoid copepods and nauplii (Fig. 4). These differences within the crustacean assemblages on the different sampling dates (1995, 2001 and 2002) were highly significant ($\chi^2 > 10$ for ostracods, amphipods, isopods, tanaids and cumaceans; df = 2; $p < 0.01$). At the same time, the average density of meiobenthos was significantly increased in sediments colonized by *Caulerpa* (2001–2002) compared to 1995 ($\chi^2 = 9.9$ for total meiofauna; df = 2; $p < 0.01$). The differences were still significant when comparing 2001 data related to sediments with and without the seaweed ($\chi^2 = 8.7$, df = 1; $p < 0.01$), but were not significant for the same sites sampled in 2002. Abundance of meiofauna in 2001–2002 sediment samples with and without *C. racemosa* are shown in Figure 5.

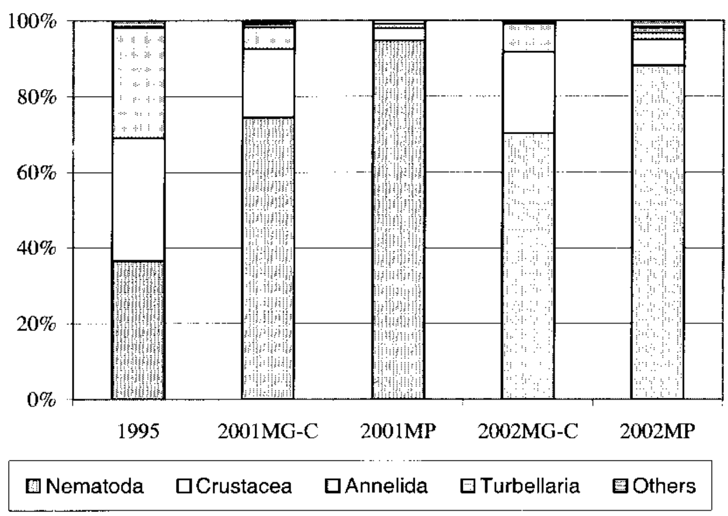

FIGURE 3 Meiofauna assemblage structure in the Gulf of Taranto. Mar Piccolo (MP), Mar Grande–Chiatona (MG–C) in 1995, 2001 and 2002. Others: Gastrotricha, Halacaroidea, Kinorhyncha and Tardigrada.

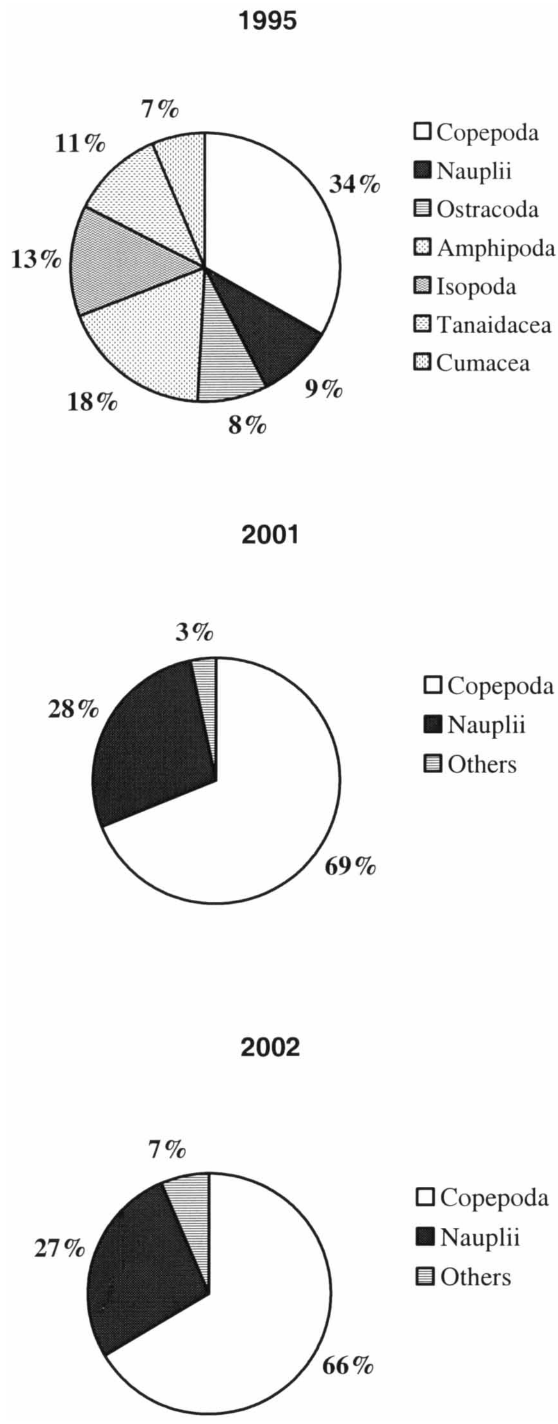

FIGURE 4 Meiobenthic crustaceans assemblage in the sediments of the Gulf of Taranto, before (1995) and after (2001–2002) *C. racemosa* invasion. Others: Amphipoda and Ostracoda.

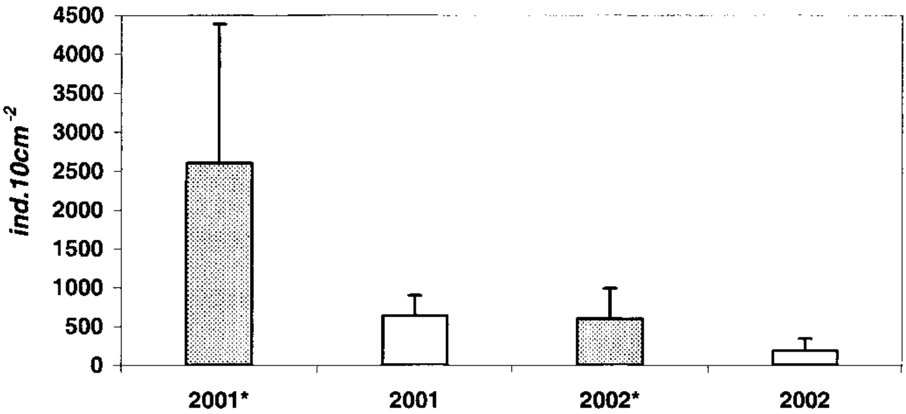

FIGURE 5 Meiofauna average density (±SD) from sediments of the Gulf of Taranto with (*) and without *C. racemosa* coverage; 2001–2002 surveys.

4 DISCUSSION

The coastal marine ecosystem of the Gulf of Taranto has been intensively modified during a long period of exposure to heavy pollution from multiple sources (Cardellicchio *et al.*, 1991). Recent investigations on Polycyclic Aromatic Hydrocarbon (PAH) concentrations of Mar Piccolo characterized this basin as one of the most contaminated of the whole Mediterranean–Atlantic region (Storelli and Marcotrigiano, 2000). To our knowledge, this investigation represents the first study of the soft-bottom meiobenthic communities in relation to the high environmental stress in this coastal area. Previous research in the Gulf of Taranto reported strong pollution impacts on various ecosystems' compartments, from the sediments to the toxicity of edible mussels (Cardellicchio *et al.*, 1989; Geraci *et al.*, 1990), and from sea water chemical quality to growth rates of colonial hydroids and macroalgae (Piraino *et al.*, 1991).

This study shows that meiofauna density and diversity are generally highly depressed in the Gulf of Taranto, especially in Mar Piccolo. The average Eh values were extremely low at the sediment surface, suggesting evident stressing conditions due to heavy organic loads. Mar Piccolo is a semi-enclosed basin that receives chronically high amounts of sewage and industrial waste. Moreover, the very low hydrodynamic regime prevents an efficient water turnover, resulting in a marked eutrophication in the whole basin. Low dissolved oxygen levels previously reported in the water column and sediments of Mar Piccolo (Cavallo *et al.*, 1999) might partly explain our findings on low meiobenthic abundance and diversity.

In the western marine area of Taranto (Chiatona) and in the Mar Grande, in front of the industrial area with several urban and agriculture waste discharges, the same parameters have slightly higher values, particularly in the sites colonized by *C. racemosa.* However, Eh profiles still show negative trends and meiobenthic community structure is widely dominated by nematodes, with most genera well adapted to strongly degraded sediments (*Theristus*, *Terschellingia* and *Desmodora*).

Generalized reduction of taxa diversity in favour of nematode dominance in degraded sediments is a widely accepted consideration in meiobenthic biomonitoring studies (Coull and Chandler, 1992; Warwick, 1981). This pattern seems to be the rule in the whole area of the Gulf of Taranto, with some local negligible differences between sites.

The presence of *C. racemosa* meadows seems to affect the meiobenthic communities in two ways. Firstly, this macroalga (with fragments falling onto the sediments) may enhance the general structural complexity of the microhabitat, offering new exploitable surfaces for meiobenthos colonization. Microenvironmental complexity can influence the structure and density of meiofaunal assemblages in different ways (Gibbons, 1988; Hall and Bell, 1988; Gee and Warwick, 1994; Danovaro and Fraschetti, 2002). This seems consistent with our findings showing higher abundance of meiofauna in areas colonized by *C. racemosa.*

Secondly, the decay of a large amount of algal biomass is likely to contribute to the organic content and eutrophication conditions of the sediment. Hypoxia and anoxia can drastically change the status of a community by killing sensitive and/or less mobile organisms and reducing suitable habitat for others (Howarth *et al.*, 2000). In our case, we recorded marked temporal changes (1995–2002) in the meiobenthic crustacean populations, with a strong rarefaction of groups like ostracods, amphipods, isopods, tanaids and cumaceans in the sediments colonized by *C. racemosa*. However, further investigations are required for a better comprehension of this local pattern of relationship between *C. racemosa* and meiobenthos. Moreover, other ecological interactions could probably be masked by the high pollution level in our study area.

The low values of meiofaunal density and diversity of the Gulf of Taranto, probably prevent such assemblages from playing their natural ecological role. Recent studies (Raffaelli, 2000) emphasize the importance of interstitial assemblages in nutrient recycling, production and energy flow in off-shore and coastal food webs.

The very low values of meiofauna density and diversity, the relevant dominance of nematodes, the absence of meiobenthic taxa more sensitive to organic pollution and the extremely low sediment redox profiles confirm that the environmental conditions in the Gulf of Taranto are strongly degraded. However, the recent contribution of the seaweed *C. racemosa* invasion must also be taken into account when examining changes in meiofaunal community structure.

Acknowledgements

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