Mediterranean Marine Science

Vol 4, No 2 (2003)

Analysis Of Macrobenthic Community Structure In Relation To Different Environmental Conditions In Three Harbours In The North Tyrrhenian Sea (Italy). Preliminary Study

R. BEDINI, M.G. CANALI, M. CAPPAGLI

doi: [10.12681/mms.232](https://doi.org/10.12681/mms.232)

Mediterranean Marine Science

Vol. 4/2, 2003, 83-97

Analysis Of Macrobenthic Community Structure In Relation To Different Environmental Conditions In Three Harbours In The North Tyrrhenian Sea (Italy). Preliminary Study

BEDINI R., CANALI M.G. and CAPPAGLI M.

Institute of Marine Biology and Ecology
p. Bovio 4, Piombino, Italy

e-mail: bedini@biomare.it

Abstract

Studies on benthic communities are being widely used in monitoring pollution effects, using both the methodologies provided from the national laws in various countries and experimental innovative methodologies of research. We have carried out a preliminary study on macrobenthic communities (zoobenthos and phytobenthos) in three harbours, one of which (Piombino) receives wastewater from industry and is also subject to heavy shipping traffic. The other two (Porto Santo Stefano and Portoferraio) enjoy great tourist traffic but no industrial waste, and they have been selected in order to find possible differences between populations of animals present in unpolluted and polluted areas. The results show that there are no outstanding differences in the sessile and sedentary bentological population parameters of the studied harbours. We probably do not have an adequate historical data set of the species living in the study areas to detect the effects of pollution, and the sessile living animal species we found may have adapted to the current situation, since living species typical of very clean waters were found.

Keyword: Macrobenthic Community, Harbours, Industries, Environmental Damage.

Introduction

The aim of this research is to analyse the current conditions of the sea area at the industrial harbour in Piombino, North Tyrrhenian Sea, Italy, (Fig. 1) in order to establish what possible differences there might be in the distribution of the organisms present at different depths and in different areas, and to compare the data of this harbour with those of two non-industrial harbours, whose populations normally colonize the nearby coastal rocks.

There is a high level of industrial activity in the area used for the purpose of this study and therefore a high level of industrial discharge into the sea. The environmental consequences might sometimes imply serious ecological damage as already observed in numerous studies of similar situations in other world locations (ABBIATI *et al.*, 1991; COGNETTI, 1992; SIMBOURA *et al.*, 1995; AIROLDI, 1998; BENEDETTI CECCHI *et al.*, 2000; COGNETTI

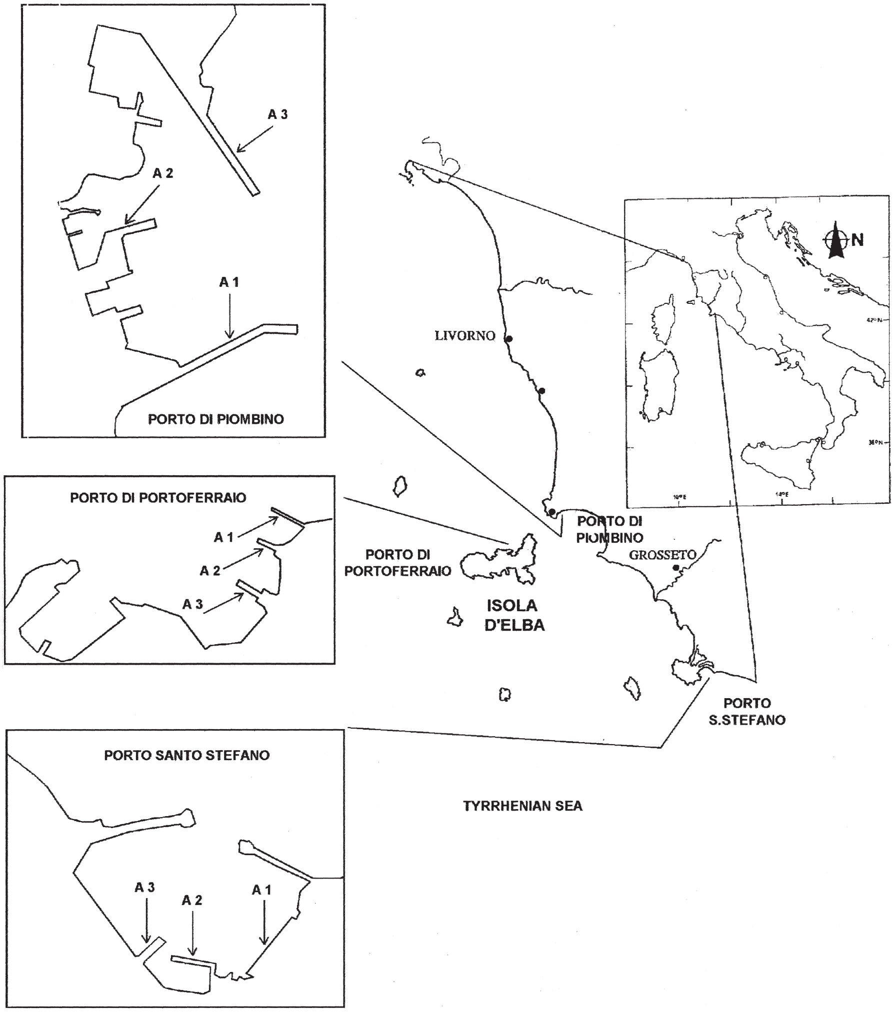

Fig. 1: Study sites along the Tuscany coast (NW Mediterranean, Italy). The three studied harbours and the respective sampling areas are shown (A1 – A3).

et al., 2000; BENEDETTI CECCHI *et al.*, 2001; HE & MORRISON, 2001; SFRISO *et al.*, 2001; DANULAT *et al.*, 2002; BACCHIOCCHI & AIROLDI, in press).

While working on subsequent research with which to compare this study, the present picture of the animal and vegetal populations living in the study area was built up through the analysis of species sensitive to conditions of stress (COGNETTI & TALIERCIO, 1969; ZUNARELLI VANDINI, 1971; COGNETTI, 1972, 1978; RICE & SIMON, 1980; COGNETTI, 1992; GOMEZ GESTEIRA & DAUVIN, 2000; SAMUELSON, 2001). The subsequent research will be used as a term of comparison.

Materials and Methods

We compared the Piombino harbour area with two other harbours: Portoferraio and Porto Santo Stefano (Fig.1), because they represent two important areas related to maritime traffic without industrial settlements. Their location on an island, and on the continental coast respectively, represent a further term of comparison.

In order to characterize biologically the three harbour areas (Sites), we chose three areas (Docks) for each harbour, with similar orientation as regards solar irradiation; in every area we chose two stations, and in every station three depths: -1. -3, -5 meters. In the harbour areas, we applied two sampling methodologies, photography by a Nikonos V camera (SVOBODA, 1985) and the removal by scratching, of (30 x 30) cm^2 samples of submerged surface for laboratory analysis (CINELLI *et al.*, 1977; SARÀ *et al.*, 1978). The sampling was carried out only once, and at a specific time, but without seasonal implications, because the study was based on sedentary species with no seasonal movement. The sampled material was carried to the laboratory at Piombino, where covering values and examples' numbers, with respect to taxa, were recorded, using a squared surface (surface in plexiglass with 1 cm. square sides). Thus we proceeded to the taxonomic determination of the animal and vegetal sampled species. Data were treated by the analysis of variance, using the GMAV programme for personal computers. Within every analysis, the homogeneity of the variances was assessed using Cochran's test. The SNK test, used afterwards for multiple comparisons, was applied in case of significance of the interaction among the different factors considered.

Results

Statistical analysis (Table 1) pointed out significant differences ($P < 0.05$) only among sites for the Porifera taxa, and only among depths for the Polychaeta Sedentaria taxa with higher covering values in Portoferraio site. A lot of Depth x Station interaction is significant according to this analysis. Therefore we can correctly point out only the significant differences among the areas (Crustacea Cirripedia) and the stations (Polychaeta Errantia), Hydrozoa and total Crustacea. Results of the SNK tests are shown in Table 2.

Table 1
Results of the analysis of variance (ANOVA) among the Piombino harbour, Porto Santo Stefano arbour and Portoferraio harbour. N.s = no significant difference.

										Crustacea					
Factors	**Algal tuft**	**Porifera**	**Sipunc-ulida**	**Polychaeta errantia**	**Polychaeta sedentaria**	**Hydrozoa**	**Bivalvia**	**Bryozoa**	**Gastro-poda**	**Total**	**Natantia**	**Isopoda**	**Brachyura**	**Anomura**	**Cirripedia**
Cochran's test	n. s.	P < 0.05	n. s.	n. s.	n. s.	P < 0.05	P < 0.05	n. s.	n. s.	n. s.	P < 0.05	n. s.	n. s.	P < 0.05	n. s.
Site = Si	n. s.	P < 0.05	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.
Area(Si) = Ar(Si)	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	P < 0.05
Station (Si x Ar) = St(Si x Ar)	n. s.	n. s.	P < 0.05	P < 0.05	n. s.	P < 0.05	P < 0.05	P < 0.05	n. s.	P < 0.05	P < 0.05	n. s.	P < 0.05	P < 0.05	P < 0.05
Depth (De)	n. s.	n. s.	n. s.	n. s.	P < 0.05	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.
Si x De	n. s.	n. s.	n. s.	n. s.	P < 0.05	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.
De x Ar(Si)	n. s.	n. s.	n. s.	P < 0.05	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.
De x St (Si x Ar)	n. s.	n. s.	P < 0.05	n. s.	P < 0.05	n. s.	P < 0.05	P < 0.05	n. s.	n. s.	n. s.	n. s.	P < 0.05	n. s.	P < 0.05

Table 2
Results of the SNK tests. PF = Portoferraio, PS = Porto Santo Stefano, PB = Piombino harbour.

Bivalvia
SNK: Si x De

Si (De)	
Depth (mts.)	**Sites**
3	PF-PS** PS-PB**
5	PS-PB**

De (Si)	
Sites	**Depth (mts.)**
PF	1-3*
PB	1-5*

SNK: St(Si x Ar)

Stations (Si x Ar)		
Sites	**Areas**	**Stations**
PF	1	1-2**
PF	2	1-2**
PS	1	1-2**
PS	2	1-2*

Crustacea total
SNK: St(Si x Ar)

Stations (Si x Ar)		
Sites	Areas	Stations
PF	1	1-2**
PF	2	1-2**
PB	3	1-2**

Crustacea natantia
SNK: St(Si x Ar)

Stations (Si xAr)		
Sites	Areas	Stations
PF	1	1-2**
PF	2	1-2**

SNK su Pr: PF-PB* PF-PS*

Crustacea anomura
SNK: St(Si x Ar)

Stations (Si xAr)		
Sites	Areas	Stations
PF	1	1-2**
PF	2	1-2**

Crustacea brachyura
SNK: De x St(Si x Ar)

Depth (Si x Ar x St)			
Sites	**Areas**	**Stations**	**Depth (mts.)**
PF	2	2	1-5** 3-5**
PB	3	2	1-5* 3-5*

Stations (Si x Ar x De)			
Sites	**Areas**	**Depth (mts.)**	**Stations**
PF	2	1	1-2**
PF	2	3	1-2**
PB	3	1	1-2**
PB	3	3	1-2**

SNK: St(Si x Ar)

Stations (Si x Ar)		
Sites	**Areas**	**Stations**
PS	2	1-2**
PB	3	1-2**

Crustacea cirripedia
SNK: De x St(Si x Ar)

Depth (Si x Ar x St)			
Sites	**Areas**	**Stations**	**Depth (mts.)**
PF	1	2	1-3** 1-5**
PF	2	1	1-3** 1-5**
PS	1	1	1-5** 3-5**
PS	2	1	1-3** 3-5**
PS	2	2	1-3** 1-5**
PS	3	2	3-5*
PB	2	2	1-3* 1-5*
PB	3	2	1-3* 1-5*

Stations (Si x Ar x De)			
Sites	**Areas**	**Depth (mts.)**	**Stations**
PF	1	3	1-2**
PF	1	5	1-2**
PF	2	1	1-2**
PF	2	3	1-2*
PS	1	3	1-2**
PS	2	3	1-2**
PS	3	5	1-2*
PB	2	1	1-2*
PB	3	1	1-2**

SNK: Aree Ar(Si): PS Area 1-3** 2-3*

Table 2 (continued)
Results of the SNK tests. PF = Portoferraio, PS = Porto Santo Stefano, PB = Piombino harbour.

Sipunculida
SNK: De x St(Si x Ar):

Depth (Si x Ar x St)			
Sites	**Areas**	**Stations**	**Depth (mts.)**
PF	1	2	1-5** 3-5**
PF	3	1	3-5**
PS	1	1	3-5**
PS	1	2	1-5**
PB	1	1	3-5*
PB	1	2	1-5* 3-5*
PB	3	1	1-5*

Stations (Si x Ar x De)			
Sites	**Areas**	**Depth (mts.)**	**Stations**
PF	1	1	1**2
PF	1	3	1**2
PF	2	1	1**2
PF	2	3	1**2
PF	2	5	1**2
PF	3	5	1*2
PS	1	3	1*2
PB	3	5	1*2

Polychaeta errantia
SNK: De x Ar(Si)

Depth (Si x Ar)		
Sites	**Areas**	**Depth (mts.)**
PB	1	1-5* 1-3**
PB	3	1-5* 1-3*

Ar (Si x De)		
Sites	**Depth (mts.)**	**Areas**
PF	5	2-3* 1-2*
PS	1	1-3* 1-2*
PS	3	1-3* 1-2*
PS	5	1-3* 2-3*
PB	1	1-2* 1-3*
PB	5	1-2* 2-3*

SNK: St(Si x Ar)

Stations (Si x Ar)		
Sites	Areas	Stations
PF	2	1**2
PF	1	1**2
PB	3	1*2

Polychaeta sedentaria
SNK: De x St(Si x Ar)

Depth (Si x Ar x St)			
Sites	**Areas**	**Stations**	**Depth**
PF	1	2	1-5*
PS	2	1	1-5*
PS	2	2	3-5*
PS	3	1	1-5*

Stations (Si x Ar x De)			
Sites	**Areas**	**Depth (mts.)**	**Stations**
PF	1	1	1**2
PF	2	1	1*2
PF	2	3	1**2
PF	2	5	1**2
PS	2	1	1*2
PS	3	1	1*2

Hydrozoa
SNK: St(Si x Ar)

Stations (Si x Ar)		
Sites	**Areas**	**Stations**
PF	1	1*2
PF	2	1**2
PB	3	1**2

Bryozoa
SNK: De x St(Si x Ar)

Depth (Si x Ar x St)			
Sites	**Areas**	**Stations**	**Depth (mts.)**
PF	1	1	1-3** 1-5**
PF	1	2	1-3** 3-5**
PF	2	1	1-3**
PS	1	2	1-5** 1-3*
PS	2	2	1-5*
PB	1	1	1-5** 3-5**
PB	1	2	1-5** 3-5**
PB	2	1	1-5** 3-5**
PB	3	1	1-3*
PB	3	2	1-3** 1-5**

Stations (Si x Ar x De)			
Sites	**Areas**	**Depth (mts.)**	**Stations**
PF	1	1	1-2**
PF	1	3	1-2**
PF	2	3	1-2**
PF	2	5	1-2**
PS	1	3	1-2**
PS	1	5	1-2**
PB	2	1	1-2*

Comparing the three study harbours (sites), we found no significant differences related to any particular taxa. Figure 2 shows the data connected with the surface covered and the number of individuals in the various taxa collected. The algal tuft appears to be homogeneous in the three harbours and at different depths. It is important to notice how the surface covered in the harbour of Piombino is larger if compared to that of the other two harbours. There are no significant differences in the presence of Polychaeta Sedentaria (its largest presence was found in Porto Santo Stefano), Polychaeta Errantia and Sipunculida. The Bryozoa are more present in the harbour of Portoferraio but well spread even in the harbours of Porto Santo Stefano and Piombino. The Hydrozoa are completely absent in the harbour of Porto Santo Stefano as are the Porifera (only one specimen of *Sycon raphanus* was sampled). The remarkable fact that these filter animals cannot be found in a harbour without industrial waste will require a more specific research, also in consideration of the fact that the very narrow entrance of this harbour and its shape prevent substantially the circulation of water with the open sea (Fig. 1). The presence of Mollusca is equivalent where a larger presence of Gasteropoda goes with a lower presence of Bivalvia, and vice versa. The Crustaceans too are spread uniformly except for a low presence of Anomura in the harbour of Piombino and especially that of Porto Santo Stefano.

A list of the vegetal and animal species living in the three sites (Table 3) was also drawn up. The recorded values, collected from every depth and site, are shown in Figure 2.

Discussion

The results of the comparative research related to the biocoenosis in the harbour areas of Piombino, Portoferraio and Porto Santo Stefano, present a relatively homogeneous situation. The algal populations are very similar, both in terms of families and distribution, in the various sites of the study and at the different depths. In considering the macrobenthos, a differentiation in the presences of some families of Annelida Polychaeta (Errantia) can be seen. Many examples of *Mytilus galloprovincialis* Lam. 1819, Mollusca, Bivalvia, Mytilidae, were observed within the harbour at Piombino, where water suction lines for cooling purposes related to the iron and steel industry are present, and are generally colonized by this species. Filter feeders Bivalve Molluscs were observed also inside the harbour at Porto Santo Stefano, - *Arca noae* L. 1758, and *Musculus marmoratus* (FORBES, 1838), Mollusca, Bivalvia, Arcidae and Mytilidae - which is rich in suspended organic substances. The species *Anomia ephippium* (L. 1758), Mollusca, Bivalvia, Anomiidae- again related to benthic presences -, is a more sensitive water quality filter feeder, and is present only in Portoferraio. A great number of *Athanas nitescens* Leach 1814, Macrura, Natantia, Alpheidae, were found only within Piombino harbour. These, in all probability, moved to this harbour area from the neighbouring *Posidonia oceanica* (L.) Delile1813 meadows. In Portoferraio many Hermit Crabs and Sponges were sampled. For the Crustacea this is in complete agreement with the data of the statistical analysis.

All the collected data show that extreme pollution situations are not present, as in all the harbour areas both vegetal and animal population are well-structured and varied. Certainly the Piombino harbour area where industrial waste waters are often released into the sea, although treated and cleaned before such release into the harbour waters, seems to be the area which must sustain a higher pressure of anthropogenic activities; the environmental situation is nevertheless similar to the situation found in the other two studied harbours, except for the *Isopoda*, absent in the harbour of Porto Santo Stefano.

The fact that colonies of *Cladocora caespitosa* (L., 1767), Cnidaria, Madreporaria,

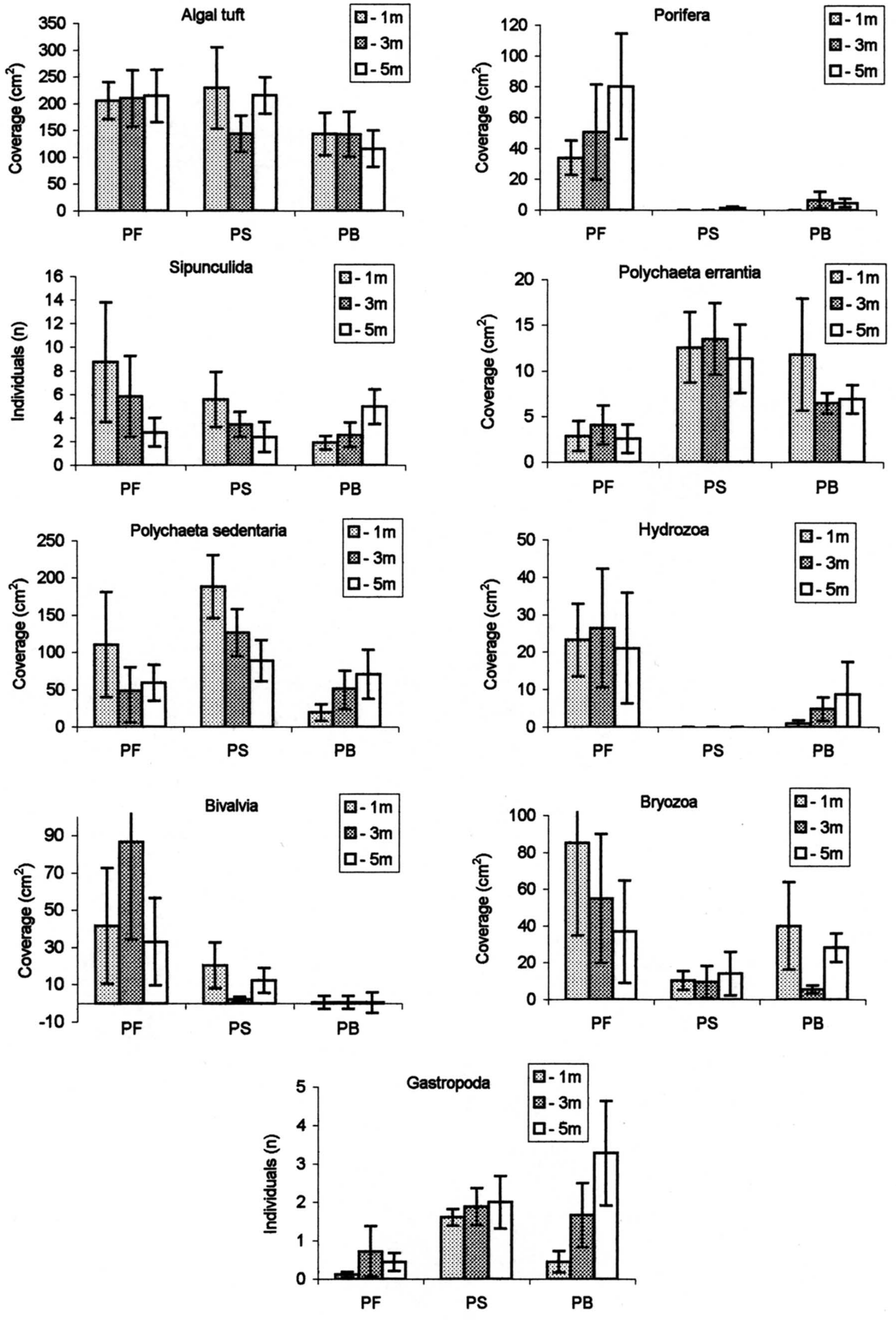

Fig. 2: Mean (n = 6) and standard error of the covering values or individuals number of the three harbours at the three depths (-1; -3; -5m). PF = Portoferraio, PS = Porto Santo Stefano, PB = Piombino harbour.

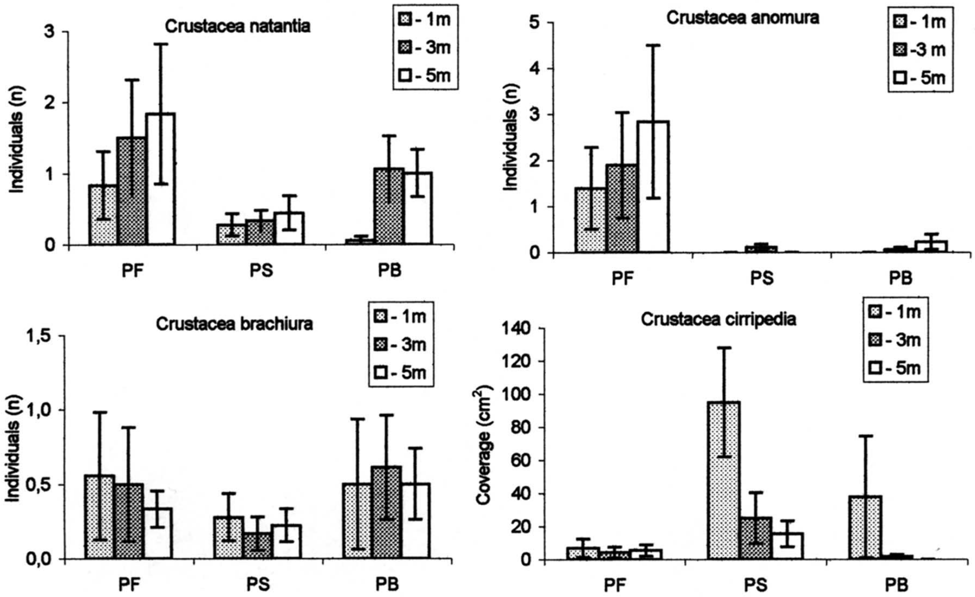

***Fig. 2** (Cont.):* Mean (n = 6) and standard error of the covering values or individuals number of the three harbours at the three depths (-1; -3; -5m). PF = Portoferraio, PS = Porto Santo Stefano, PB = Piombino harbour.

Favidae, Opistobranchia and examples of *Scyllarus arctus* (L., 1758), Macrura, Reptantia, Scyllaridae (station 1) and *Palinurus elephas* (Fabr., 1787), Macrura, Reptantia, Palinuridae, (station 3) have been found and photographically documented during an underwater general survey in the Piombino harbour, is extremely interesting. These species are thought to be indicators of good water quality (Dauer & Alden III, 1995). This is therefore, presumably, an indicator that the individuals present, which tolerate the current environmental stress, are genetically adapted.

Finally, such wide research in terms of number and variety of classified species, indicates that the most suitable methodologies (which require improvement), should use the response to the stress induced by harbour waters and by substances thought toxic, as used in another research line of this study, on particular ubiquitous species like film-feedings Sipunculida or filter feedings like Bryozoa, Polychaeta or Mollusca Bivalvia. Thus the level of the environmental damage could be evaluated compared with the intensity of the stress induced and recorded on this species with already confirmed 'recording' techniques regarding the stress reaction. The usual methodologies, based on the presence/absence or on the occasional demographic explosion of some presumed water-quality indicators species, overall Polychaeta, do not always give scientifically certain results. Therefore living species, thought not to be compatible with the found environmental situation (such as above mentioned ones), but that adapt themselves (COGNETTI & MALTAGLIATI, 2000) over time, and probably represent the result of an environmental selection, can be found.

Acknowledgements

For their collaboration in this research we thank:

Prof. Gianfranco Sartoni, Vegetal Biology Department of the University of Florence, for identification of the sampled algae; Frigate Commander, Massimo Di Marco of

Table 3
Species -list of animal and vegetal species found in the three harbours;
PF = Portoferraio, PS = Porto Santo Stefano, PB = Piombino harbour.

SITE			PF	PS	PB
SIPUNCULIDA	*Aspidosyphon*	*muelleri muelleri*		x	x
	Golfingia	*elongata*	x		x
	Golfingia	*vulgaris*		x	x
	Phascolosoma	*agassizi agassizi*		x	x
	Phascolosoma	*granulatum*	x	x	x
POLYCHAETA SEDENTARIA	*Armandia*	*polyophthalma*			x
	Branchiomma	*lucullanum*	x		x
	Cirratulus	*cirratulus*		x	x
	Dodecaceria	*concharum*	x	x	x
	Eupolymnia	*nebulosa*		x	x
	Ficopomatus	*enigmaticus*		x	x
	Filograna	*implexa*			x
	Heterocirrus	*bioculatus*			x
	Hydroides	*uncinata*	x	x	x
	Mercierella	*enigmatica*		x	x
	Pherusa	*plumosa*		x	
	Polycirrus	*aurantiacus*			x
	Polycirrus	*medusa*			x
	Pomatoceros	*triqueter*		x	
	Pomatostegus	*polytrema*			x
	Serpula	*vermicularis*	x	x	x
	Spirorbis	*borealis*			x
	Spirorbis	*pagenstecheri*			x
	Vermiliopsis	*langheransi*		x	x
	Vermiliopsis	*infundibulum*	x	x	x
POLYCHAETA ERRANTIA	*Arabella*	*iricolor*	x	x	x
	Autolytus	*paradoxus*	x		x
	Callizona	*setosa*			x
	Ceratonereis	*costae*	x	x	x
	Ceratonereis	*hircinicola*		x	x
	Dorvillea	*rubrovittata*	x	x	
	Eteone	*picta*			x
	Eulalia	*bilineata*		x	x
	Eulalia	*macroceros*	x	x	x
	Eulalia	*viridis*		x	
	Eunice	*harassii*	x	x	x
	Eunice	*russeauii*		x	x
	Eunice	*siciliensis*	x	x	x
	Eunice	*torquata*	x	x	x
	Eunice	*vittata*	x	x	
	Euphrosyne	*foliosa*			x
	Eusyllis	*blomstrandi*			x
	Exogone	*brevipes*	x		
	Exogone	*gemmifera*	x		x
	Glycera	*alba*		x	x
	Glycera	*rouxi*		x	
	Goniada	*emerita*			x

Table 3 (Continued)

SITE			PF	PS	PB
	Haplosyllis	*spongicola*			x
	Harmotoe	*extenuata*	x	x	
	Harmotoe	*impar*	x	x	
	Harmotoe	*lunulata*		x	
	Hediste	*diversicolor*	x	x	x
	Kefersteinia	*cirrata*		x	x
	Lepidonotus	*clava*	x	x	x
	Lepidonotus	*squamatus*		x	x
	Lisidice	*ninetta*	x	x	x
	Lumbrinereis	*coccinea*	x	x	x
	Lumbrinereis	*fragilis*	x	x	x
	Lumbrinereis	*gracilis*	x	x	x
	Lumbrinereis	*impatiens*	x	x	x
	Lumbrinereis	*latreilli*	x	x	x
	Lumbrinereis	*paradoxa*	x	x	x
	Marphisa	*belli*	x	x	
	Marphisa	*sanguinea*	x	x	x
	Marphisa	*fallax*		x	x
	Neanthes	*caudata*		x	
	Neanthes	*fucata*	x	x	x
	Nematonereis	*unicornis*		x	x
	Nereis	*caudata*	x	x	x
	Nereis	*hircinicola*	x	x	
	Nereis	*longissima*	x		
	Nereis	*pelagica*	x	x	
	Nereis	*rava*		x	x
	Nereis	*zonata*		x	x
	Perinereis	*cultrifera*	x	x	x
	Phyllodoce	*laminosa*		x	
	Platynereis	*coccinea*	x	x	
	Platynereis	*dumerilii*	x	x	x
	Podarke	*pallida*			x
	Polynoe	*scolopendrina*	x		x
	Schistomeringos	*rudolphii*		x	x
	Sthenelais	*boa*	x	x	x
	Syllis	*cucullata*		x	x
	Syllis	*gracilis*	x		x
	Syllis	*hyalina*	x		x
	Syllis	*prolifera*	x	x	x
	Syllis	*variegata*		x	x
	Staurocephalus	*kefersteini*	x		
	Tripanosyllis	*zebra*	x		
MOLLUSCA GASTROPODA	*Alvania*	*lineata*		x	
	Bittium	*reticulatum*	x	x	
	Crepidula	*fornicata*			x
	Nassarium	*incrassata*	x	x	x
	Rissoa	*variabilis*	x	x	x
	Vermetus	*triquetrus Ant.*	x	x	
MOLLUSCA PLACOPHORA	*Chiton*	*olivaceus*	x	x	x

Table 3 (Continued)

SITE			PF	PS	PB
MOLLUSCA BIVALVIA	*Anomia*	*ephippium*	x		x
	Arca	*noae*	x	x	x
	Cardita	*trapezia*		x	x
	Chama	*gryphoides*			x
	Gastrochaena	*dubia*	x	x	x
	Mytilus	*galloprovincialis*		x	x
	Ostrea	*edulis*	x	x	
	Parvicardium	*exiguum*		x	x
	Striarca	*lactea*	x	x	x
CRUSTACEA BRACHIURA	*Eurynome*	*aspera*	x	x	
	Maja	*verrucosa*	x		
	Pachygrapsus	*marmoratus*			x
	Pilumnus	*hirtellus*	x	x	x
CRUSTACEA NATANTIA	*Alpheus*	*dentipes*	x	x	x
	Alpheus	*glaber*	x		
	Alpheus	*macrocheles*	x	x	
	Athanas	*nitescens*		x	x
	Palaemon	*serratus*	x		x
	Processa	*acutirostris*	x	x	
	Processa	*edulis*	x		x
	Thoralus	*cranchii*	x		
	Upogebia	*deltaura*		x	
	Upogebia	*tipica*		x	
CRUSTACEA ANOMURA	*Calcinus*	*tubularis*	x	x	
	Cestopagurus	*timidus*	x		
	Clibanarius	*erythropus*	x	x	
	Galathea	*squamifera*	x		x
	Pagurus	*anachoretus*	x		
	Pagurus	*chevreauxi*	x		
	Pisidia	*bluteli*			x
	Pisidia	*longimana*			x
CRUSTACEA ISOPODA	*Anthura*	*gracilis*	x		x
	Cyathura	*carinata*	x		
	Gnathia	*maxillaris*	x		x
	Gnathia	*phallonajopsis*	x		x
	Gnathia	*vorax*	x		
	Jaeropsis	*brevicornis*			x
CRUSTACEA AMPHIPODA	*Dexamine*	*spiniventris*			x
	Gammarus	*aequicauda*		x	x
	Hyale	*schmidtii*	x		x
	Leucothoe	*spinicarpa*	x		x
	Lysianassa	*longicornis*			x
	Maera	*inaequipes*			x
	Microdeutopus	*grillotalpa*			x
	Orchestia	*gammarella*			x
	Tritaeta	*gibbosa*			x
CRUSTACEA ANISOPODA	*Apseudes*	*latreillei*			x
	Laophonte	*cornuta*			x
	Leptochelia	*savigny*	x		x

Table 3 (Continued)

SITE			PF	PS	PB
	Tanais	*cavolinii*	x		x
PORIFERA	*Crambe*	*crambe*			x
	Hymenacidion	*sanguinea*	x		
	Myxilla	*incrustans*	x		
	Sycon	*raphanus*		x	x
	Spirastrella	*cunctatrix*	x		
HYDROZOA	*Bougainvillia*	*ramosa*	x		
	Eudendrium	*rameum*	x		x
	Halecium	*halecinum*			x
	Nemertesia	*antennina*	x		
ANTHOZOA	*Cladocora*	*caespitosa*			x
BRYOZOA	*Aetea*	*truncata*			x
	Bugula	*neritina*			x
	Bugula	*turbinata*	x		x
	Cellaria	*sinuosa*	x		
	Cellepora	*pumicosa*	x		
	Chlidonia	*pyriformis*			x
	Crisia	*eburnea*			x
	Crisia	*ramosa*			x
	Cryptosula	*pallasiana*	x		
	Fenestrulina	*malusii*		x	
	Idmonea	*atlantica*	x		
	Nolella	*dilatata*			x
	Paludicella	*articulata*			x
	Savygniella	*lafontii*			x
	Schizobrachiella	*sanguinea*	x		x
	Schismopora	*armata*		x	
	Scrupocellaria	*reptans*			x
	Sertularia	*perpusilla*		x	
PHORONIDEA	*Phoronis*	*hippocrepia*			x
NEMERTINEA	*Cerebratulus*	*fuscus*	x		
ECHINIIDAE	*Psammechinus*	*microtuberculatus*	x		
TUNICATA	*Didemnum*	*maculosum*			x
	Microcosmus	*sulcatus*		x	
	Styela	*partita*	x		x
ENTHOPHYSALIDACEAE	*Entophysalis*	*deusta*		x	
	Chaetomorpha	*sp.*	x		
CLADOPHORACEAE	*Cladophora*	*coelothrix*	x	x	x
	Cladophora	*echinus*	x	x	x
	Cladophora	*prolifera*	x	x	x
	Cladophora	*cfr.vagabunda*	x	x	
VALONIACEAE	*Valonia*	*utricularis*		x	
CHEATOSIPHONACEAE	*Blastophysa*	*rhizopus*		x	
DASYCLADACEAE	*Acetabularia*	*acetabulum*	x		x
	Dasycladus	*vermicularis*	x		
UDOTEACEAE	*Flabellia*	*petiolata*	x	x	x
	Halimeda	*tuna*		x	
RHODOMELACEAE	*Chondria*	*sp.*	x		
	Herposiphonia	*sp.*			x

Table 3 (Continued)

SITE			PF	PS	PB
	Herposiphonia	*secunda*		x	
	Herposiphonia	*tenella*		x	
	Laurencia	*microcladia*	x		
	Lophosiphonia	*cristata*	x	x	
	Lophosiphonia	*obscura*		x	
	Polysiphonia	*scopulorum*	x	x	x
	Polysiphonia	*sertularioides*			x
	Womersleyella	*setacea*	x	x	x
DASYACEAE	*Dasya*	*rigidula*	x		
	Heterosiphonia	*crispella*	x	x	x
	Heterosiphonia	*secunda*	x		x
CERAMIACEAE	*Acrothamnion*	*preissii*		x	
	Aglaothamnion	*tenuissimum*	x		x
	Antithamnion	*cruciatum*	x		x
	Antithamnion	*pumula*	x		
	Antithamnion	*heterocladum*		x	x
	Ceramium	*sp.*			x
	Ceramium	*ciliatum*		x	
	Ceramium	*cimbricum*	x		
	Ceramium	*codii*	x	x	x
	Ceramium	*diaphanum*	x		
	Ceramium	*flaccidum*		x	x
	Griffithsia	*sp.*	x		
	Pterothamnion	*crispum*		x	
	Spiridia	*filamentosa*	x		
	Wrangelia	*penicillata*		x	
CORALLINACEAE	*Amphiroa*	*rigida*		x	
	Corallina	*sp.*			x
	Corallina	*elongata*		x	
	Corallinacee	*incrostanti*	x	x	x
GELIDIACEAE	*Gelidiella*	*pannosa*		x	
	Gelidium	*pusillum*	x	x	x
PEYSSONNELLIACEAE	*Peyssonnellia*	*bornetii*		x	
	Peyssonnellia	*squamaria*	x		
ERYTHROPELTIDIACEAE	*Erythrotrichia*	*carnea*		x	
GONIOTRICHACEAE	*Stylonema*	*alsidii*		x	
SPHCELARIACEAE	*Sphacelaria*	*cirrosa*	x	x	x
STYPOCAULACEAE	*Halopteris*	*filicina*	x	x	
DICTYOTACEAE	*Dictyota*	*dichotoma*	x	x	
	Padina	*pavonica*	x	x	
CUTLERIACEAE	*Aglazonia*	*parvula*	x		
HILDEBRANDIACEAE	*Hildebrandia*	*sp.*	x		
CAULACANTHACEAE	*Caulacanthaus*	*ustulatus*	x		
CHAMPIACEAE	*Lomentaria*	*sp.*	x		
CYSTOCLONIACEAE	*Rhodophyllis*	*divaricata*			x
PHYLLOPHORACEAE	*Schottera*	*nicaeense*			x
ECTOCARPACEAE	*Ectocarpus*	*siliculosus*			x
BONNEMAiSONiACEAE	*Falkenbergia*	*hildebrandtii*			x

Portoferraio Harbour Office, Vessel Lieutenant Giovanni Stella of Piombino Harbour Office and Vessel Lieutenant Edoardo Balestra of Porto Santo Stefano Harbour Office, for their collaboration and their permission granted to sample in harbour areas; Chief of the Piombino Fire Brigade, Franco Miliani, for support given during field research; the Piombino Harbour Dockers' Company.

We particularly thank: Magona D'Italia S.p.A., Dalmine S.p.A., Tioxide Europe S.r.l., Nuova Solmine S.p.A., Ecosanitas S.p.A., Lucchini Siderurgica S.p.A., Solvay Chimica S.p.A. e "Associazione Industriali" of Livorno for promoting and financing this research.

KODAK S.p.A. provided the colour film used to complete this study.

References

ABBIATI, M., BUFFONI, G., DI COLA, G. & SANTANGELO, G., 1991. Red coral population dynamics: stability analysis and numerical simulation of time evolution of perturbed states. In O. Ravera (Ed.): Terrestrial and aquatic ecosystems: perturbation and recovery: 219-228. Ellis Horwood Limited.

AIROLDI, L., 1998. Roles of disturbance, sediment stress, and substratum retention on spatial dominance in algal turf. *Ecology,* 79: 2759-2770.

BACCHIOCCHI, F. & AIROLDI, L., in press. Structure, distribution, and dynamics of epibiota on different typologies of coastal defence works. Estuar. Coast. Shelf Sci.

BENEDETTI CECCHI, L., BULLERI, F. & CINELLI, F., 2000. The interplay of physical and biological factors in maintaining mid-shore and low-shore assemblages on rocky coasts in the northwest Mediterranean. *Oecologia,* 123: 406-417.

BENEDETTI CECCHI, L., PANNACCIULLI, F., BULLERI, F., MOSCHELLA, P.S., AIROLDI, L., RELINI, G. & CINELLI, F., 2001. Predicting the consequences of anthropogenic disturbance: large-scale effects of removing dominant species on rocky shores. *Marine Ecology Progress Series,* 214: 137-150.

CINELLI, F., FRESI, E., MAZZELLA, L., PANSINI, M., PRONZATO R. & SVOBODA, A., 1977. Distribution of phyto- and zoocenosis along a light gradient in a superficial cave. p.173-183. In: *Biology of benthic organisms,* Oxford, Pergamon Press.

COGNETTI, G., 1972. Distribution of the Polychaeta in polluted waters, *Revue Internationale d'Oceanographie Medicale,* 25: 23-24

COGNETTI, G., 1978. On some aspects of the ecology of the benthic littoral polychaetes. *Bollettino Zoologico,* 45: 145-154

COGNETTI, G., 1992. Colonization of stressed coastal environments. *Marine Pollution Bulletin,* 24, (1): 12-14.

COGNETTI, G. & TALIERCIO, P. 1969. Policheti indicatori dell'inquinamento delle acque. *Pubblicazioni Stazione Zoologica di Napoli,* 37, (suppl.): 149-154

COGNETTI, G. & MALTAGLIATI, F., 2000. Biodiversity and adaptative mechanisms in brackish water fauna. *Marine Pollution Bullettin* 40, (1): 7-14

COGNETTI, G., LARDICCI, C., ABBIATI, M., CASTELLI, A., 2000. The Adriatic Sea and the Tyrrhenian Sea , in C. Sheppard (Ed.): Seas at the Millennium- An environmental evaluation, 1: 267-284. Elsevier Science Ltd., London.

DANULAT, E., MUNIZ, P., GARCIA-ALONSO, J. & YANNICELLI, B., 2002. First assessment of the highly contaminated harbour of Montevideo, Uruguay. *Marine Pollution Bulletin* 44, (6): 554-565.

DAUER, D.M. & ALDEN III, R.W., 1995. Long-term trends in the macrobenthos and water quality of the lower Chesapeake Bay (1985-1991). *Marine Pollution Bullettin,* 30, (12): 840-850

GOMEZ GESTEIRA, G.L. & DAUVIN, J.-C., 2000. Amphipods are good bioindicators of the impact oil spills on soft-bottom macrobenthic communities. *Marine Pollution Bullettin,* 40, (11): 1017-1027

HE, Z. & MORRISON, R.J., 2001. Changes in the marine environment of Port Kembla Harbour, NSW, Australia, 1975-1995: a review. *Marine Pollution Bulletin,* 42, (3): 193-201.

RICE, S.A. & SIMON, J.L., 1980. Intraspecific variation in the pollution indicator polychaete *Polydora ligni* (Spionidae), *Ophelia,* 19: 79-115

SAMUELSON, G.M., 2001. Polychaetes as indicators of environmental disturbance on subarctic tidal flats, Iqaluit, Baffin Island, Nunavut Territory. *Marine Pollution Bullettin,* 42, (9): 733-741

SARÀ, M., BALDUZZI, A., BOERO, F., PANSINI, M., PESSANI, D. & PRONZATO, R., 1978. Analisi di un popolamento bentonico di falesia del Promontorio di Portofino: dati preliminari. *Bollettino Museo Istituto Biologico Universitario,* 46: 119-137

SFRISO, A., BIRKEMEYER, T. & GHETTI, P.F., 2001. Benthic macrofauna changes in areas of Venice lagoon populated by seagrass or seaweeds. *Marine Environmental Research,* 52, (4): 323-349

SIMBOURA, N., ZENETOS, A., PANAYOTIDIS, P. & MAKRA, A., 1995. Changes in benthic community structure along an environmental pollution gradient. *Marine Pollution Bullettin,* 30, (7): 470-474

SVOBODA, A., 1985. Diver-operated cameras and their marine biological uses. p.17-36. In: *Underwater photography and television for scientists,* edited by J.D. George, G.I. Lythgoe, London, Clarendon Press

ZUNARELLI VANDINI, R., 1971. Observation on a population of *Podarke pallida* (Polychaeta, Hesionidae) in heavily polluted waters. *Bollettino Zoologico,* 45: 249-249