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ANALYSIS OF MACROBENTHIC COMMUNITY STRUCTURE IN THREE AREAS OF THE GULF OF TRIESTE

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ABSTRACT

The Gulf of Trieste is a shallow bay characterized by high primary production and a wide range of temperature, salinity and dissolved oxygen at the bottom. In the last decades it was affected by particular events such as red tides, recurrent phenomena of anoxia, and appearance of mucous aggregates. To evaluate the macrobenthic community structure of the Gulf of Trieste, an ecological study was carried out from 1990 to 1993, on three stations along a sedimentary gradient. Statistical analysis was performed using non-parametric methods and fuzzy sets analysis on abundance data. There is clear evidence of differences among the three zones in terms of species composition and trophic structure. Throughout the studied area there is a dominance of Corbula gibba, *a species well adapted to live in instable mixed muddy bottoms.*

Key words: macrobenthos, community structure, Gulf of Trieste
Ključne besede: makrobentos, struktura združbe, Tržaški zaliv

INTRODUCTION

The species composition in a macrobenthic community depends on various ecological factors; among these the most important is the nature of the substratum (Gray, 1974).

In general, fine sediments, whose grains are highly packed, prevent the presence of an interstitial fauna, due to poor water circulation and low oxygen tension; on the other hand, medium and fine sands have an abundant fauna with more diversified adaptive strategies (Gray, 1981).

The aim of this work is to evaluate the macrobenthic community structure along a sedimentary gradient in three stations of the Gulf of Trieste, analyzing data acquired from 1990 to 1993.

MATERIALS AND METHODS

Study site

The Gulf of Trieste is a shallow bay (maximum depth 25 m) characterized by wide range of water temperatures, high sedimentation rate and low transparency of coastal waters. In the last decade this area was affected by biological phenomena such as red tides, hypoxia,

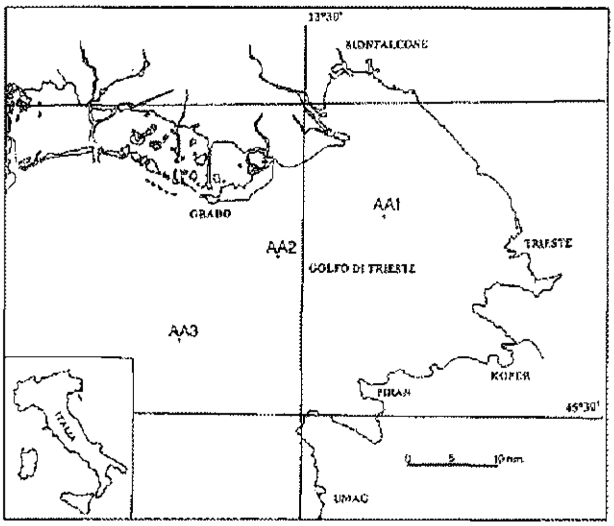

Fig. 1: Map of the studied area showing the sampling station.
Sl. 1: Zemljevid preučevanega območja s postajami za vzorčanje.

anoxia (Orel *et al.*, 1993a; Stachowitsch, 1984) and mucus aggregates (Orel *et al.*, 1993b), which have influenced the macrobenthic community structure more or less severely (Brizzi *et al.*, 1994).

The stations (fig. 1) are located at depths ranging from 19 to 21 m, in areas where the above-mentioned phenomena occurred. In particular st. AA1 was affected by anoxia in September 1990, when the oxygen value on the bottom fell to 0.37ml/l. During the summer of 1991, considerable amounts of mucus aggregates, more abundant in st. AA1 and less extensive in st. AA2 and AA3, were observed.

The st. AA1 is characterized by sandy pelitic sediment (Brambati *et al.*, 1983), with 10% of sand, the st. AA2 by very sandy pelitic sediment (62% of sand) and the st. AA3 by pelitic sand (92% of sand); moreover, the last two have a high content of organic detritus.

Sampling procedure

At each station five replicate samples were collected twice a year (A=03/1990, B=09/1990, C=07/1991, D=11/1991, E=03/1992, F=10/1992, G=06/1993, H=12/1993) with a 0.1m^2 van Veen grab. Faunal samples were placed on a 1 mm mesh sieve and finer sediment was washed out. The material remaining on the sieve was preserved in buffered 5% formalin. Samples were sorted and major taxa were identified and counted.

Statistical analyses

Species with a total abundance higher than ten individuals were considered for analyses; moreover, the species of the five replicates were combined to form one sample.

Data were arranged in a 24 samples x 143 species matrix, which was percentualized per samples and normalized per species. In order to verify the differences in the faunal composition of the stations, a classification using the average linkage algorithm (Anderberg, 1973) was done on the similarity matrix ("similarity ratio") (Westoff & Van der Maarel, 1978) among the samples.

Using non-parametric variance analysis, the Kruskal-Wallis test, discriminant species were selected among stations. They can show a random distribution in the stations less or equal to 1%.

The stations were defined as fuzzy sets (Zadeh, 1965) using the method suggested by Feoli & Zuccarello (1986, 1988, 1992). Each station represents a set in which the degree of linkage between the objects (samples or species) and the station is a membership function varying as a continuum between 0 and 1. Fuzzy sets were used as an ordination axis to represent samples and species along a sedimentary gradient.

By means of the explained covariance for each station, the species were arranged on the basis of their importance in defining the community structure (Orloci, 1978).

In order to analyze the trophic structure of the biocoenoses, a principal component analysis on the abundance data referred to the four main feeding groups (carnivores, filter-feeders, surface deposit-feeders, subsurface deposit-feeders) was carried out.

For the statistical processing, the Matedit (Burba *et al.*, 1992) and Syntax (Podani, 1988) programmes were used.

RESULTS AND DISCUSSION

During the studied period, 105 species were identified for st. AA1, 155 for st. AA2 and 168 for st. AA3. In all the stations the richest group was represented by polychaetes, followed by molluscs. These two taxa exceeded 80% of the total abundance, whereas crustaceans and echinoderms showed lower values (fig. 2). The most abundant groups were polychaetes in st. AA2 and AA3, and molluscs, mainly respresented by the bivalve *Corbula gibba*, in st. AA1 (fig. 3).

In marine soft sediments, polychaetes are generally numerically dominant among macrofaunal taxa, constituting between 50 and 80% of the total macrofaunal individuals (Jumars & Fauchald, 1977). They are abundant both in bottoms characterized by fine sedimentation or affected by stress, and in well-structured ecosystems.

The classification of the samples is shown in fig. 4. In the dendrogram, two main groups are identified: the first one (I) is formed by samples of st. AA1, while the second one (II) includes the sandiest stations. The latter pre-

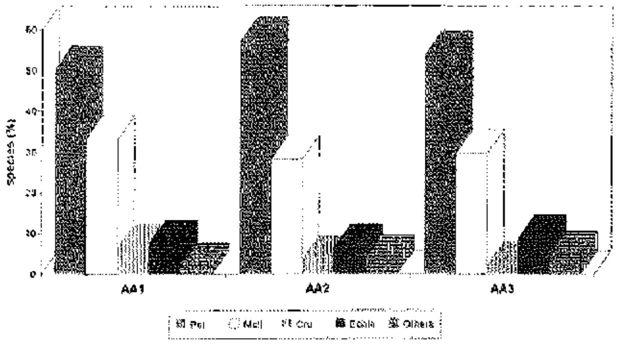

Fig. 2: Total number of species (percentage) of polychaetes, molluscs, crustaceans, echinoderms and other groups sampled in the three stations.
Sl. 2: Skupno število vrst (v odstotkih) mnogoščetincev, mehkužcev, rakov, iglokožcev in drugih skupin, vzorčenih na treh postajah.

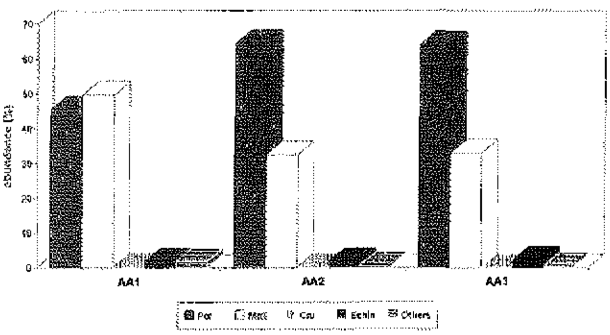

Fig. 3: Total number of individuals (percentage) of polychaetes, molluscs, crustaceans, echinoderms and other groups sampled in the three stations.
Sl. 3: Skupno število osebkov (v odstotkih) mnogoščetincev, mehkužcev, rakov, iglokožcev in drugih skupin, vzorčenih na treh postajah.

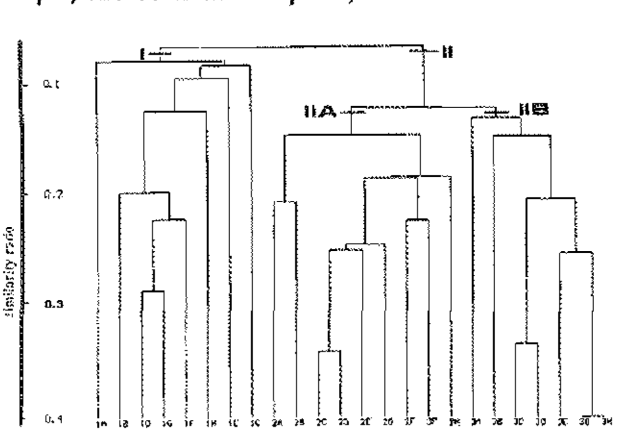

Fig. 4: Classification of samples with average linkage based on the similarity ratio matrix.
Sl. 4: Dendrogram podobnosti v sestavi favne med postajama, izdelan na osnovi matrike podobnostnih indeksov.

sents two sub-clusters: IIA includes all the samples of st. AA2 and one of st. AA3, and IIB the remaining samples of st. AA3.

This classification shows that the benthic communities in the three stations are different, independent of the sampling period. The ordination also shows three main groups: these are located along the sedimentary gradient and are formed by the samples of each station (fig. 5).

After having obtained the subdivision of the samples into three groups representing the three stations, the discriminant species for this characterization (tab. 1) were identified using non-parametric variance analysis. The discriminant species have been ordered with respect to the same axes defined by the stations (AA1 and AA3) located at the extremes of the sedimentary gradient (fig.6). This ordination is overlapped on the one defined by the samples. The overlapping shows that the species more typical of st. AA1 are the mollusc *Nucula nucleus*, considered to be a species resistent to oxygen depletion (Wilson & Davis, 1984), and the polychaetes *Maldane glebifex* and *Spiochaetopterus costarum*, typical of sediments characterized by high organic content. Moreover, *M. glebifex* builds a very thick mud tube that can stabilize sediments because it increases the compactness (Glémarec *et al.*, 1986).

The bivalve *Tellina serrata* can be found only in st. AA2; this is a characteristic species of the "detritic muddy biocoenosis" (Picard, 1965). Other typical species of this station include the polychaetes *Owenia fusiformis, Glycera rouxii, Lumbrineris latreilli, Drilonereis filum,* which usually inhabit muddy-sandy bottoms.

St. AA3 is characterized by species which are typical of sandy sediments, such as bivalve *Clausinella brognartii* and the polychaetes *Nematonereis unicornis, Jasmineira elegans, Clymenura clypeata* and *Prionospio malmgreni.*

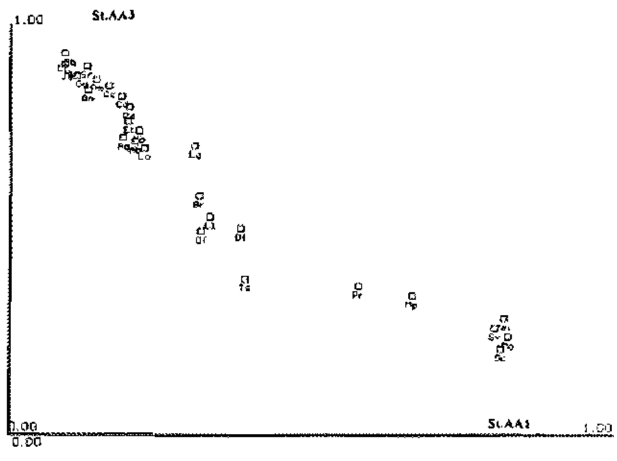

Fig. 5: Ordination of samples according to fuzzy sets of st. AA1 and st. AA3.
Sl. 5: Razvrstitev vzorcev glede na "meglene množice" (fuzzy sets) na postajah AA1 in AA3.

	St. AA1								St. AA2								St.AA3							
	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
Maldane glebifex (Mg)	131	126	123	222	24	126	97	56	88	74	100	119	115	94	63	5		3	2	1		2		
Nucula nucleus (Nn)	13	4	3	3	3	8	4	9	2	1	6	5	3	3	2	4	3		3		1	2	1	1
Spiochaetopterus costarum (Sc)	2	7	2	10	8	11	24	31	7	5	7	15	10	6	20	4								
Serpula vermicularis (Sv)								17			2	3	2	2	1	3								
Melinna palmata (Mp)	7	12	2	19	1	30	11	16	13	3	16	6	18	31	7	34	2		7	3	3	3		
Pitar rudis (Pr)		9	2	3	1	2	2	9	13	13	11	17	8	13	15		5	2	3				2	1
Tellina serrata (Ts)		1							13		2	4	4	2	5	3							1	
Drilonereis filum (Df)						11				3	3	3	18	15	4	4		2	3	1	3	4	2	1
Lumbrineris latreilli (Ll)	2	1		1		15	1	15	20	8	41	15	39	40	40	62	10	3	5	2	24	24	16	15
Owenia fusiformis (Of)									47	23	19	8	18	14	12	3	10	1	13	2	3	3	4	1
Glycera rouxii (Gr)		1				2		3	5	1	8	6	2	4	5	34	5		5	2	5	7	1	7
Lumbrineris gracilis (Lg)	22	1	1	10		2		1	47	13	68	67	4	3	8	16	103	8	60	36	2	5	33	41
Laevicardium oblongum (Lo)										1	1	3	4	2	1		7	1	2	1	1	3		2
Marphysa bellii (Mb)				2				1	5	3	8	5	3	4	4	5	13	4	9	4	3	4	8	14
Aponuphis bilineata (Ab)			1	2					82	63	189	128	174	88	48	65	297	85	155	67	53	33	160	139
Piromis eruca (Pe)									2		1	1	1	1	1	3	17			5	1		1	2
Euclymene lumbricoides (El)									2	5	1		1	10		1	5		12	3		14	7	10
Arubelia geniculata (Ag)											2	1	2	4	3	3	3		1	4	2	2	4	3
Chone duneri (Cd)				1					5		1	2	3	1	1	6	15	7	10	18	1	3	1	
Clymenura clypeata (Cc)										1	5	3	1	2		8	38	1	31	11		1	11	4
Prionospio malmgreni (Pm)									2			1				6	23		7	3	4	1		14
Goniada maculata (Gm)									8	3	8	4	2	2	3	8	2	5	37	14	25	21	28	24
Schistomeringos rudolphii (Sr)											1		1		1	1	37		6	5	5	1	4	5
Ophiothrix quinquemaculata (Oq)													2	2			2	2	7	4	5		4	
Clausinella brognartii (Cb)																			1	3		1	3	2
Nematonereis unicornis (Nu)						1					1			2		1	12	4	9	6	8	7	18	26
Jasmineira elegans (Je)										2				1	1	2	17	18	5	2	1	4	1	14

Table 1: Discriminant species between the stations.
Tabela 1: Diskriminantne vrste med postajami.

The species that explain more than 85% of covariance of the individual stations are reported in tab. 2; the percentage of explained covariance for each species represents its importance in the community structure. In st. AA1 *Corbula gibba* accounts for 83% of the relative importance and the polychaete *Maldane glebifex* for 10%. Generally *C. gibba* is abundant in areas characterized by environmental instability (Bonvicini-Pagliai & Serpagli, 1988) and in zones with periodic oxygen depletion, where it becomes numerically dominant (Aleffi *et al.*, 1993; Zavodnik *et al.*, 1994). In fact, st. AA1 is affected by recurring hypoxia that sometimes reaches values near zero, as in September 1990 (Brizzi *et al.*,1994).

	St.AA1	St.AA2	St.AA3
Corbula gibba	83.00	59.69	60.13
Aponuphis bilineata	-	-	30.68
Eunice vittata	3.79	11.54	-
Maldane glebifex	10.14	14.27	-

Table 2: Relative importance of species on the basis of the percentage of explained covariance.
Tabela 2: Relativen pomen vrst na osnovi deleža pojasnjene kovariance med postajami.

In st. AA2 *C. gibba* is still dominant, but its importance is reduced, whereas an increased percentage of *Maldane glabifex and Eunice vittata* can be found.

In st. AA3 *C. gibba* is again the most important species, followed by the polychaete *Aponuphis bilineata;* the latter is abundant in fine sand (Dauvin & Ibanez, 1986), but also in coarse sand (Picard, 1965).

The three stations are well separated, based on the ordination derived by the analysis of the feeding groups (fig. 7), in which the samples are placed along the sedimentary gradient. The evident separation of the station samples in the plane defined through the first two principal components, suggests stable community trophic structure in each station.

The samples of st. AA1 tend to aggregate toward high values of subsurface deposit-feeders and filter-feeders; the latter generally live on sandy bottoms, so their abundance on muddy bottoms could be linked with the high sedimentation rate and with the density of seston in the Gulf of Trieste (Fedra, 1977). These particular conditions allow these organisms to have a sufficient food supply. St. AA2 samples are scattered mainly toward the surface deposit-feeders, and those of st. AA3 towards the carnivores.

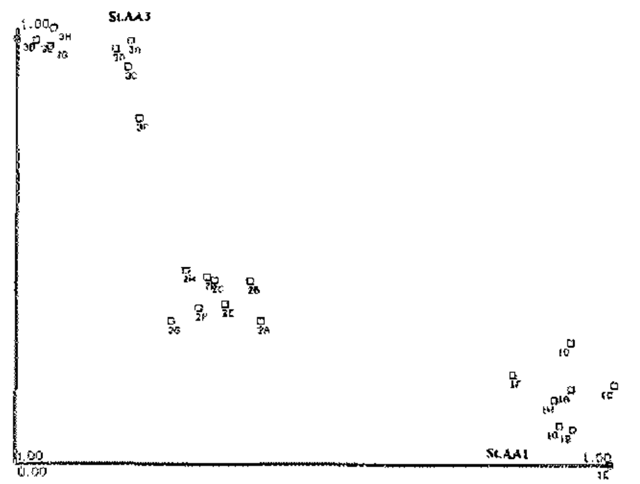

Fig. 6: Ordination of discriminant species according to the fuzzy sets of st. AA1 and st. AA3.
Sl. 6: Razvrstitev diskriminantnih vrst glede na "meglene množice" na postajah AA1 in AA3.

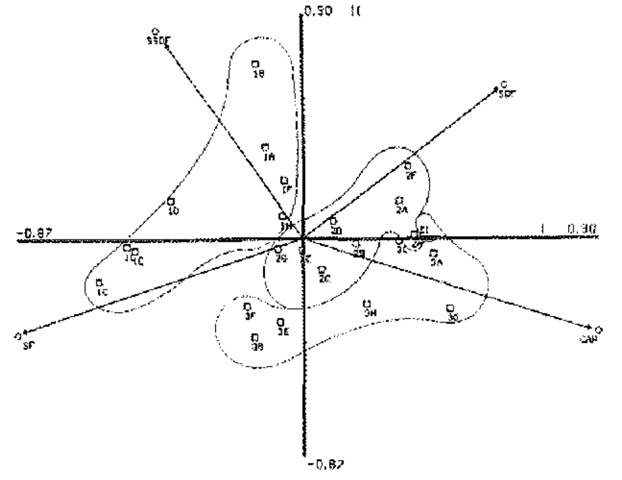

Fig. 7: Ordination of samples and feeding groups according to the first two principal components (PCA).
Sl. 7: Prostorska razvrstitev vrednosti faktorjev za sleherni vzorec in prehranjujočih se skupin na podlagi metode PCA (principal component analysis).

CONCLUSION

Analyzing the macrobenthic community structure of three areas in the Gulf of Trieste, reveals differences among the zones. Some species are only present in st. AA1 or in st. AA3, while st. AA2, characterized by mixed sediments, has a community which is formed by an overlap of populations of the two other stations located at the extremes of the sedimentary gradient. Evident differences appear in the abundances related to the trophic structure: in muddy sediments, the population is mainly formed by subsurface deposit-feeders, while on sandy-detritic bottoms carnivores are abundant. Since the latter occupy a high level in the food chain, their presence demonstrates that the community has reached a good level of structuring (Odum, 1961; Hily, 1984).

Corbula gibba, abundant in bottoms characterized by environmental instability (Russo, 1982; Salen-Picard, 1981), is dominant in all of the stations. This is due to the unstable conditions in the Gulf of Trieste, which is frequently affected by biological phenomena such as anoxia and mucus aggregates and by anthropogenic influences such as very intensive fishing activities throughout the area.

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POVZETEK

Poglavitne značilnosti plitvega Tržaškega zaliva so visoka primarna produkcija in precejšnje razlike v temperaturi, slanosti in raztopljenem kisiku na njegovem dnu. V zadnjih desetletjih je bil zaliv pod močnim vplivom rdečih plim, nenehnega pomanjkanja kisika in pojavljanja sluzastih agregatov. Da bi ocenili sestavo makrobentoške združbe v Tržaškem zalivu, so avtorji članka med letoma 1990 in 1993 opravili temeljito ekološko študijo na treh postajah vzdolž usedlinskega grebena. Statistična analiza je bila napravljena ob uporabi neparametričnih metod in analizi "meglenih množic" (fuzzy sets) podatkov številčnosti. Ugotovljene so bile očitne razlike v sestavi vrst in trofični strukturi med tremi predeli. Povsod v preučevanem območju je bila ugotovljeno prevladovanje školjke Corbula gibba, *ki je dobro prilagojena življenjskim razmeram na nestabilnem mešanem blatnem dnu.*

REFERENCES

Aleffi, F., Brizzi, G., Del Piero, D., Goriup, F., Landri, P., Orel, G. & Vio, E. (1993): Prime osservazioni sull'accrescimento di *Corbula gibba* (Mollusca, Bivalvia) nel Golfo di Trieste (Nord Adriatico). Biol.Mar., suppl. al Notiz. S.I.B.M., 277-280.

Anderberg, M. R. (1973): Cluster Analysis for Application. Academic Press, New York.

Bonvicini-Pagliai, A.M. & Serpagli, F. (1988): *Corbula gibba* (Olivi) as a time recorder of environmental stress. A first contribution. Rapp. Comm. Int. Mer Medit., 31, 2.

Brambati, A., Ciabatti, M., Fanzutti, G.P., Marabini, F. & Marocco, R. (1983): A new sedimentological textural map of the Northern and Central Adriatic Sea. Boll. Ocean. Teor. Appl., 1(4), 267-271.

Brizzi, G., Orel, G., Aleffi, F., Landri, P., Goriup, F., Del Piero, D. & Vio, E. (1994): Evoluzione del popolamento macrobentonico in una stazione soggetta ad ipossia ed anossia del Golfo di Trieste (Alto Adriatico). Biol. Mar. Medit., 1(1), 249-253.

Burba, N., Feoli, E., Malaroda, M. & Zuccarello, V. (1992): Un sistema Informativo per la Vegetazione. Manuale di utilizzo del Package. Collana Quaderni CETA n.2, Udine.

Dauvin, J-C. & Ibanez, F. (1986): Variations à long-terme (1977-1985) du peuplement des sables fins de la Pierre Noire (baie de Morlaix, Manche occidentale): analyse statistique de l'évolution structurale. Hydrobiologia, 142, 171-186.

Fedra, K. (1977): Structural features of the North Adriatic benthic community. In: B.F. Keegan, P.O. Ceidigh, P.J.S. Boaden (eds) Biology of benthic organisms, 11th European Symposium on Marine Biology, Pergamon Press, Oxford, 233-246.

Feoli, E. & Zuccarello, V. (1986): Ordination based on classification: yet another solution? Abstracta Botanica 10, 203-219.

Feoli, E. & Zuccarello, V. (1988): Syntaxonomy: a source of useful fuzzy sets for environmental analysis? Coenoses, 3, 141-147.

Feoli, E. & Zuccarello, V. (1992): Fuzzy Sets and structural changes in forest succession: an example from broad leaved forests of N.E. Italy. Coenoses, 7(2), 81-90.

Glémarec, M., Le Bris, H. & Le Guellec, C. (1986): Modifications de écosistèmes des vasières cotières du su-Bretagne. Hydrobiologia, 142, 159-170.

Gray, J. (1974): Animal-sediment relationships. Oceanogr.Mar.Biol.Rev., 12, 223-261.

Gray, J. (1981): The ecology of marine sediments. Cambridge Univ. Press, Cambridge.

Hily, C. (1983): Variabilité de la macrofaune benthique dans les milieux hyper-trophiques de la rade de Brest. Thèse Doct. Sci., Univ. Brest, 1-358.

Jumars, P.A. & Fauchald, K. (1977): Feeding and Metabolism. Between-comunity contrasts in successful polychaete feeding strategies. In: Ecology of marine benthos, ed. B.C. Coull., University of South Carolina Press, Columbia, S.C., 1-20.

Odum, P.E. (1961): Fundamentals of ecology. W.B. Saunders Company, Philadelphia, 2nd edition, 1-546.

Orel, G., Fonda Umani, S. & Aleffi, F. (1993a): Ipossie e anossie di fondali marini. L'Alto Adriatico e il Golfo di Trieste. Regione Autonoma Friuli-Venezia Giulia, 1-104.

Orel, G., Vio, E., Del Piero, D., Brizzi, G. & Aleffi, F. (1993b): Mare sporco, popolamenti bentonici e pesca. Biologia Marina, Suppl. Notiz. SIBM, 1, 13-18.

Orloci, L. (1978): Multivariate analysis in vegetation research. Junk, The Hague 2nd ed.

Picard, J. (1965): Recherches qualitatives sur les biocoenoses marines des substrats meubles dragables de la région marseillaise. Rec. Trav. St. Mar. Endoume, 52(36), 1-160.

Podani, J. (1988): SYN-TAX III. User's manual. Abstr. Bot. 12, Suppl. 1, 1-183.

Russo, G.F. (1982): Distribuzione della malacofauna di fondo mobile nella Rada di Augusta. Boll. Mus. Ist. Biol. Univ. Genova, 50 suppl., 325-331.

Salen-Picard, C. (1981): Evolution d'un peuplement de vase terrigéne cotière soumis a des rejets de dragages, dans le Golf de Fos. Tethys, 10, 83-88.

Stachowitsch, M. (1984): Mass mortality in the Gulf of Trieste: the course of community destruction. P.S.Z.N.I.: Mar. Ecol., 5(3), 243-264.

Westoff, V. & Maarel Van Der, E. (1978): The Braun-Blanquet approach 2nd ed. In: R.H.

Whittarker (ed.), Classification of Plant Community. Junk, The Hague.

Wilson, J.G. & Davis, J.P. (1984): The effect of environmental variables on the oxygen consumption of the protobranch bivalve *Nucula turgida* (Leckenby and Marshall). J.moll.Stud., 50, 73-77.

Zadeh, A. (1965): Fuzzy sets. Inform. Control, 8, 338-353.

Zavodnik, D., Travizi, A. & Jaklin, A. (1994): Phytoplankton bloom consequences on benthic organisms. In: UNEP/FAO - Final Reports on Research Projects Dealing with Eutrophication Problems. MAP Tech. Repts Ser. n. 78, UNEP, Athens, 91-120.