Mar. Life 1994 - Vol. 4 (1) : 31 - 39

Classification of soft-bottom amphipod communities off the Apulian coast (Mediterranean Sea)

Classification des communautés de Crustacés Amphipodes des côtes des Pouilles (mer Méditerranée)

Giovanni Diviacco*, Alessandra Somaschini**
* I.C.R.A.M., via L. Respighi, 5 - 00197 Roma, Italia
** Museo civico di zoologia, viale del Giardino zoologico, 20 - 00197 Roma, Italia

Mots clés : *Amphipodes, sédiments, matière organique, granulométrie, classification, Méditerranée, Italie.*
Key-words : *Amphipoda, sediment-type, organic matter, cluster analysis, Mediterranean Sea, Italy.*

RÉSUMÉ

Diviacco G., A. Somaschini, 1994 - [Classification des communautés des Crustacés Amphipodes des côtes des Pouilles (mer Méditerranée)]. Mar. Life **4** (1) : 31 - 39.

Le groupe des Crustacés Amphipodes est l'un des plus importants dans les fonds meubles de la Méditerranée mais les données sur la distribution des espèces demeurent incomplètes. Cette étude se propose de caractériser les peuplements benthiques de fonds meubles sur la base des Amphipodes et d'étudier la distribution des espèces les plus abondantes par rapport à la composition du sédiment. Une étude quantitative a été effectuée le long de la côte des Pouilles (Italie), avec 87 points d'échantillonnages situés entre 7 m et 125 m de profondeur. L'analyse de groupement sur les données faunistiques a mis en évidence la présence de deux groupes de stations : le premier comprend les fonds sableux et détritiques jusqu'à la profondeur de 75 m ; le second comprend les stations de vase plus profondes. Les stations sableuses côtières sont les plus riches en nombre d'espèces et d'individus. Elles sont caractérisées par U. elegans, A. brevicornis, A. sarsi, A. typica, C. runcicorne, B. guilliamsoniana, P. longicaudata *et* H. massiliensis. *Les fonds graveleux d'origine biodétritique, qui sont situés à une profondeur intermédiaire, sont caractérisés par* L. costae *et* O. similis. *Les fonds vaseux plus profonds sont les plus pauvres en espèces et aussi en individus ; ils sont caractérisés par* M. schmidtii *et* H. nirae.

ABSTRACT

Diviacco G., A. Somaschini, 1994 - Classification of soft-bottom amphipod communities off the Apulian coast (Mediterranean Sea). Mar. Life **4** (1) : 31 - 39.

A total of 87 soft-bottom grab samples were collected at depths ranging from 7 m to 125 m along the Apulian coast (Southern Italy). The sediment-type and the amphipod community structure were then analysed. Cluster analysis of the faunal data revealed the presence of assemblages according to the grain-size and the amount of organic matter. Fine-sand amphipod community is richer in species and individuals than muddy community which is characterized by few dominant species.

INTRODUCTION

The benthic soft-bottom fauna of the Mediterranean Sea has been the subject of many synecological studies (Picard J., 1965 ; De Gaillande, 1968 ; Fébvre Chevalier, 1969 ; Bourcier *et al.*, 1979 ; Picard C., 1971 ; Gambi and Fresi, 1981 ; Fresi *et al.*, 1983 ; Relini *et al.*, 1986). Many authors have pointed out the importance of the depth gradient in structuring benthic communities, which acts as a super-parameter for benthic communities. The most important abiotic factors influencing community structure are the sediment-type and the input of organic matter (Gray, 1981 ; Mirza and Gray, 1981 ; Intes and Le

Loeuff, 1986 ; Eleftheriou and Basford, 1989 ; Cocito *et al.*, 1990).
Amphipod Crustaceans, along with Polychaetes and Molluscs, are among the most important taxa in Mediterranean soft-bottoms, both in abundance and species composition (Scipione, 1989 ; Scipione *et al.*, 1989). Now, in Mediterranean literature, many papers have uptill dealt with the analysis along the depth gradient of single taxa distribution such as Polychaetes (Gambi and Giangrande, 1982 ; 1986 ; Giangrande and Gambi, 1982 ; Gambi *et al.*, 1983 ; Salen-Picard, 1987), Molluscs (Russo and Fresi, 1983; Russo *et al.*, 1984), and Echinoderms (Focardi *et al.*, 1982 ; Colognola *et al.*, 1984). Despite that, and although the literature about Amphipods is very rich, and a wealth of information exists about the systematics of this group (see Bellan-Santini *et al*, 1982 ; 1989, 1993 for a review), information on the ecological distribution of some soft-bottom species is still incomplete. Contributions to the ecology of some Mediterranean soft-bottom species have been provided by Cecchini and Parenzan, 1934 ; Ledoyer, 1968, 1969, 1977 ; Bellan-Santini and Ledoyer, 1973 ; Falciai and Spadini, 1985 ; Scipione, 1989 ; Marti *et al.*, 1990 ; Somaschini and Ardizzone, 1991. Information on the ecology of some species is also available for the European Atlantic coasts : Laborda Navia, 1983 ; Marques and Bellan-Santini, 1985 ; Maze and Laborda, 1986.
During a research project along the Apulian coast carried out by the ENEA (1986) physico chemical and benthic features of the sea bottom were studied. This paper presents results about the Amphipods and attempts to characterize the soft-bottom communities studied, showing the relationship between species distribution and sediment composition.

MATERIALS AND METHODS

1- Study area

The investigated area covers the Jonian and the Adriatic Seas facing the Apulian coast, between the mouths of the Biferno and Bradano rivers (Figure 1). The environmental investigations were carried out by the ENEA and dealt with the oceanography, lithology, hydrography, geomorphology, sedimentology, and macrobenthic communities of this area (ENEA, 1986). This study enabled classification of three main environmental units (Damiani *et al.*, 1988). The first unit extends between the mouths of the Biferno and the Ofanto rivers, where the coast is generally low and there are many rivers. These are responsible for the deposition of the very fine sediment and for the amount of organic matter which, thus, becomes intensively mineralized. The second environmental unit comprises the southern part of the Apulian coast from the mouth of the Ofanto river on the Adriatic Sea and the Gulf of Taranto on the Jonian Sea. The water is very clear due to the absence of rivers. Here the rocky coasts are of a calcareous origin and sediments are generally composed of very coarse and unsorted biogenic sand of biodetritic origin. The coastal area is composed of soft-bottoms interspersed by *Posidonia oceanica* (L.) Delile seagrass bed and biogenic formations (Coral-

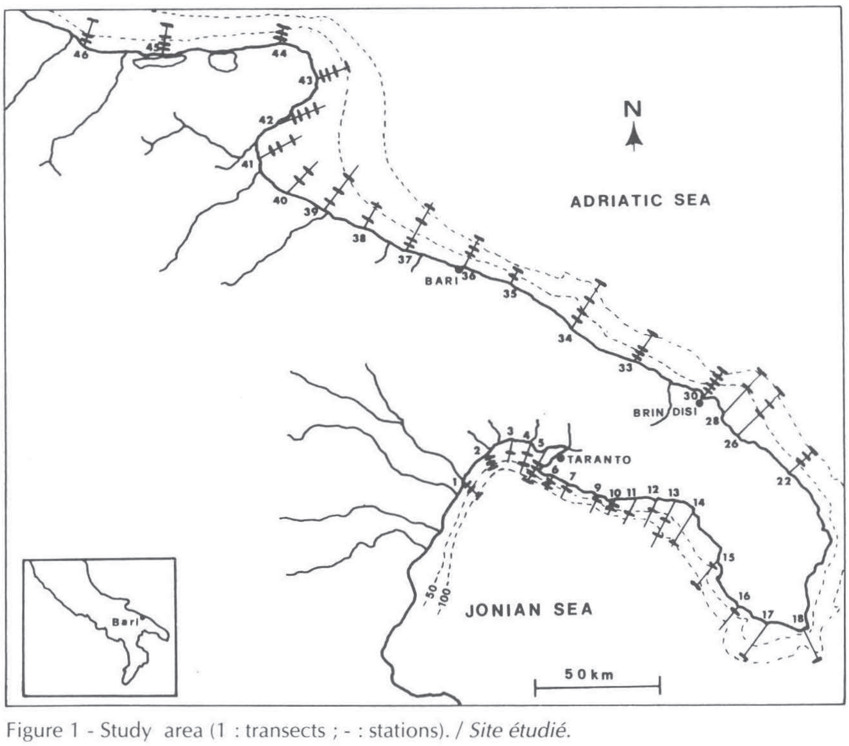

Figure 1 - Study area (1 : transects ; - : stations). / *Site étudié.*

Table I - List and location of sampling stations. Stars indicate stations where Amphipods were collected. / *Liste des points d'échantillonnage. Les Amphipodes ont été recueillis dans les stations marquées d'un astérique.*

STATION	DEPTH (m)	LAT. N	LONG. E	STATION	DEPTH (m)	LAT. N	LONG. E
1A*	14	40°24'45"	16°54'06"				
1B*	25	40°24'30"	16°54'24"	33D	50	40°47'35"	17°40'43"
1D*	122	40°24'19"	15°54'42"	33F*	100	40°50'57"	17°42'52"
2A*	13	40°27'42"	16°57'30"	34C*	30	40°55'28"	17°22'15"
2B*	23	40°27'33"	16°57'42"	34D*	50	40°57'52"	17°22'42"
2C*	50	40°27'10"	16°58'00"	34E*	75	40°58'13"	17°25'43"
3A*	25	40°29'38"	17°03'12"	34F*	120	40°59'22"	17°27'12"
4A*	25	40°27'45"	17°07'24"	35B*	20	41°00'26"	17°12'48"
4B	48	40°26'45"	17°06'45"	35C*	50	41°01'24"	17°13'54"
5A	40	40°25'35"	17°11'04"	36C*	50	41°09'08"	16°53'42"
5B	36	40°24'57"	17°10'39"	36D*	75	41°10'05"	16°54'21"
5C	56	40°24'42"	17°10'19"	36F	112	41°12'17"	16°55'48"
5D	102	40°23'48"	17°09'42"	37A	10	41°13'05"	16°34'48"
6B*	37	40°22'42"	17°14'32"	37B*	20	41°13'18"	16°35'05"
6C	45	40°22'21"	17°14'24"	37D*	75	41°17'18"	16°38'39"
7A*	37	40°21'28"	17°18'25"	37E	100	41°20'00"	16°40'06"
9A*	20	40°19'24"	17°24'08"	38B*	21	41°19'18"	16°23'51"
10A*	18	40°17'30"	17°30'12"	38D*	50	41°22'10"	16°27'14"
10B*	30	40°17'09"	17°30'00"	39A	10	41°22'02"	16°13'45"
11C*	57	40°15'18"	17°33'45"	39C*	33	41°26'02"	16°19'39"
12B*	47	40°15'48"	17°39'32"	39D	50	41°28'21"	16°23'18"
13D*	65	40°12'00"	17°43'06"	40A*	10	41°26'15"	16°03'07"
13E	115	40°12'22"	17°42'24"	40B	15	41°27'28"	16°05'53"
14E*	100	40°07'33"	17°46'48"	41A	10	41°35'06"	15°56'42"
15A	20	40°06'03"	17°57'37"	41B	13	41°35'36"	16°02'30"
15E	115	40°03'18"	17°50'13"	41C	15	41°35'48"	16°07'58"
16A	35	39°56'54"	18°00'34"	42A*	7	41°38'58"	15°59'02"
16B*	40	39°57'10"	18°00'05"	42B	10	41°38'51"	16°01'02"
17F*	97	39°44'11"	18°04'37"	42C	18	41°39'11"	16°08'15"
18D	128	39°42'20"	18°20'55"	42D	15	41°39'40"	16°12'37"
22C*	50	40°24'27"	18°19'28"	43A*	11	41°49'28"	16°12'12"
22D	75	40°24'49"	18°19'48"	43B	20	41°49'42"	16°15'21"
22E	100	40°37'32"	18°22'37"	43C*	30	41°49'51"	16°18'07"
26C	50	40°33'47"	18°10'35"	43D*	50	41°49'38"	16°20'39"
26D*	75	40°35'20"	18°12'00"	44A	10	41°55'20"	16°07'42"
26E	100	40°37'00"	18°14'00"	44B*	20	41°56'48"	16°08'15"
28D	50	40°28'24"	18°08'14"	44C*	50	41°59'15"	16°11'26"
28F	100	40°40'00"	18°10'55"	45A*	10	41°55'18"	15°29'18"
30B	20	40°39'56"	17°58'40"	45B*	20	41°58'28"	15°29'05"
30C*	30	40°40'00"	17°58'48"	45C	50	42°00'34"	15°29'01"
30D	50	40°40'18"	17°59'05"	45D*	75	42°02'03"	15°28'51"
30E*	75	40°40'20"	17°59'20"	46A*	10	41°56'50"	15°07'15"
30F*	100	40°41'26"	18°00'27"	46B*	21	41°59'36"	15°08'42"
33B*	20	40°46'48"	17°40'08"	46D*	75	42°04'48"	15°10'27"

ligenous) up to 60 m depth. The last environmental unit extends North of the Taranto Gulf and is very similar to the first, due to the presence of many rivers. Despite that, the continental shelf is very narrow and the sea bottom reaches 200 m depth a few miles from the shore.

2- Sampling procedures

Eighty-seven sampling stations were located along thirty-five transects in an area about 780 km in length (Table I). Sampling depth ranges from 7 m to 125 m (Figure 1). Sampling stations were preferentially located on the northern part of both the Adriatic and the Jonian Sea, because of the abundance of *Posidonia oceanica* beds and Coralligenous formations in the southern area.

A core was collected in each station for sedimentological analysis (Viel *et al.*, 1986 a). The grain size analysis was performed by sieving sediment through different mesh sizes (2, 1, 0.5, 0.25, 0.125, and 0.063 mm). Silt and clay fractions were analysed with a coulter counter. The Wentworth (1922) granulometric scale was used to classify sediments into gravel, sand, silt and clay (Bedulli *et al.*, 1986).

Chemical analyses of sediments were conducted on the finest fraction (< 0.063 mm) (Viel *et al.*, 1986b). The amount of calcium-carbonate ($CaCO_3$) origina-

Table II - Main characteristics of sampling stations./ *Caractéristiques principales des points d'échantillonnage.*

CLUSTER GROUP	STATION (m)	DEPTH %	GRAV %	SAND %	SILT %	CLAY %	C %	N %	C/N	$CaCO_3$ %
Ia	1A	14	0	91.46	5.34	3.20	2.27	0.12	19	16.50
	2A	13	0	88.35	7.28	4.37	1.86	0.07	27	7.60
	4A	25	0	56.27	31.27	12.46	1.41	0.11	13	32.10
	7A	37	0.37	87.66	10.71	1.26	2.39	0.13	18	44.50
	9A	20	0	97.64	2.15	0.21	3.12	0.16	19	41.50
	45A	10	0	89.16	5.42	5.42	1.65	0.04	41	14.20
	1B	25	0	92.05	4.65	3.30	2.15	0.09	24	15.70
	2B	23	0	82.06	12.52	5.42	1.28	0.09	14	12.10
	10B	30	0.20	83.76	14.68	1.36	2.10	0.16	14	44.10
	16B	40	0	97.12	1.99	0.89	2.16	0.17	13	43.40
	45B	20	0	33.29	57.24	9.47	0.71	0.04	18	26.90
	2C	50	0	8.64	71.44	19.92	0.64	0.06	11	17.70
	34C	30	7.76	75.01	8.03	9.20	1.62	0.10	16	34.60
	13D	65	4.65	47.27	22.60	25.48	1.80	0.18	10	36.80
Ib	10A	18	0	96.83	2.66	0.51	2.16	0.12	18	35.90
	42A	7	0	7.81	86.38	5.81	1.22	0.04	31	26.30
	46A	10	0	85.20	8.88	5.92	1.23	0.02	62	21.10
	36C	30	1.75	80.62	9.91	7.72	2.42	0.09	27	33.00
Ic	6B	57	9.50	76.30	8.24	5.96	2.14	0.15	14	39.80
	33B	20	15.92	66.72	9.13	8.23	2.60	0.18	20	34.60
	11C	57	6.65	67.69	15.14	10.52	2.22	0.18	12	51.40
	34D	50	8.76	42.97	17.86	30.41	0.87	0.07	12	28.30
IIa	37B	20	0	17.45	47.88	34.67	1.50	0.06	25	21.50
	35C	50	0	3.56	49.96	46.48	0.52	0.06	9	21.50
	43C	30	0	.58	63.13	36.29	0.99	0.04	25	24.40
	ID	122	0	1.28	59.72	39.00	1.16	0.04	29	15.50
	43D	50	0	.11	53.94	45.95	0.93	0.06	16	25.30
	45D	75	0	.19	65.39	43.42	0.67	0.06	13	27.60
	46D	75	0	.16	52.42	47.42	0.71	0.07	10	28.30
	30E	75	0	16.76	36.29	46.95	1.20	0.09	13	25.50
	17F	97	0	48.55	22.12	29.33	1.38	0.09	15	24.60
	33F	100	0	.39	35.46	64.15	1.21	0.03	40	19.80
	34F	120	1	20.16	26.96	51.88	0.75	0.06	12	22.60
IIb	40A	10	4.06	66.31	10.01	19.62	1.02	1.09	11	19.20
	43A	11	0	33.63	47.79	18.58	1.05	0.05	21	19.60
	38B	21	0	6.01	57.62	36.37	0.35	0.06	6	19.90
	46B	21	0.20	29.03	50.95	19.82	0.76	0.04	19	27.60
	22C	50	0.44	70.98	18.78	14.80	1.21	0.08	15	33.00
	36C	50	0.13	7.68	38.74	53.50	1.16	0.07	15	20.20
	39C	33	0	.17	42.53	57.30	0.84	0.06	14	23.10
	44C	50	0	.18	51.93	47.94	0.87	0.05	17	24.60
	38D	50	0	.04	41.28	58.68	0.66	0.06	11	23.30

ting from calcareous debris (calcimetry by CO_2 release) was used to detect the presence of detritic bottoms, and to evaluate the heterogeneity of substrata. The percentage of organic carbon (C) was measured by means of the oxydation with potassium bicromate. Nitrogen was measured using the Kjedhal method (Viel *et al.*, 1986a; Bedulli *et al.*, 1986). The amount of organic matter as the percentage of carbon and nitrogen was used to evaluate the C/N ratio which indicates the state of organic matter.

Benthic fauna was collected in the same sampling stations by means of a Van Veen grab (0.1 m^2, two grabs by station), sieved through a 1 mm mesh and preserved with 10 % buffered formalin (Bedulli *et al.*, 1986). Amphipod Crustaceans were identified to species level and counted after sorting.

3- Data analysis

Cluster analysis on faunal data was performed to study the affinity between sampling stations (Q mode). Species and stations without any specimen, or those with only one specimen were removed from the matrix before the computer analysis. A selected set of 42 species and 42 stations was then used in the clustering technique. The Spearman

Table III - List of species sampled. P = Presence (number sightings of the species) ; A = Abundance (total number of individuals collected)./*Liste des espèces recueillies. P = degré de présence (nombre d'espèces retrouvées) ; A = degré d'abondance (nombre d'individus échantillonnés).*

Species	P	A
AMPELISCIDAE		
Ampelisca brevicornis (A. Costa, 1853)	7	42
Ampelisca diadema (A. Costa, 1853)	13	61
Ampelisca gibba G.O. Sars, 1882	1	9
Ampelisca ledoyeri Bellan-Santini and Kaim-Malka, 1977	2	7
Ampelisca multispinosa Bellan-Santini and Kaim-Malka, 1977	1	1
Ampelisca pseudosarsi Bellan-Santini and Kaim-Malka, 1977	3	5
Ampelisca pseudospinimana Bellan-Santini and Kaim-Malka, 1977	1	29
Ampelisca sarsi Chevreux, 1888	8	42
Ampelisca tenuicornis Liljeborg, 1855	6	24
Ampelisca typica (Bate, 1856)	16	73
Haploops nirae Kaim Malka, 1976	2	15
AORIDAE		
Aora spinicornis Afonso, 1976	1	1
Lembos angularis Ledoyer, 1970	1	44
Lembos spiniventris (Della Valle, 1893)	1	4
Leptocheirus mariae Karaman, 1973	2	7
Leptocheirus pectinatus (Norman, 1869)	3	3
Microdeutopus versiculatus (Bate, 1856)	1	1
COROPHIIDAE		
Corophium annulatum Chevreux, 1908	1	1
Corophium runcicorne Della Valle, 1893	4	65
Siphonoecetes dellavallei Stebbing, 1899	2	2
Siphonoecetes neapolitanus Schiecke, 1979	1	1
DEXAMINIDAE		
Dexamine spinosa (Montagu, 1813)	1	1
EURISIDAE		
Apherusa cfr. vexatrix Krapp-Schickel, 1979	1	1
Eusirus longipes Boeck, 1861	1	1
ISAEIDAE		
Photis longicaudata (Bate and Westwood, 1893)	6	83
LEUCOTHOIDAE		
Leucothoe incisa Robertson, 1892	3	4
Leucothoe occulta Krapp-Schickel, 1975	1	1
Leucothoe pachycera Della Valle, 1893	1	5
LYSIANASSIDAE		
Hippomedon bidentatus Chevreux, 1903	2	2
Hippomedon massiliensis Bellan-Santini, 1965	15	30
Ichnopus taurus Della Valle, 1893	1	1
Lepidepecreum longicorne (Bate and Westwood, 1861)	2	2
Lysianassa costae Milne Edwards, 1830	6	36
Lysianassa plumosa Boeck, 1871	3	4
Orchomene humilis (A. Costa, 1853)	1	12
Orchomene similis (Chevreux, 1912)	1	12
Orchomenella nana (Kroeyer, 1846)	2	2
Perrierella audouiniana (Bate, 1857)	1	1
Socarnes filicornis (Heller, 1866)	2	9
Tryphosites longipes (Bate and Westwood, 1861)	2	3
MELITIDAE		
Melita gladiosa Bate, 1862)	1	1
Ceradocus semiserratus (Bate, 1862)	1	1
Cheirocratus sundevallii (Rathke, 1843)	2	3
Maera grossimana (Montagu, 1808)	2	8
Maera schmidtii Stephensen, 1915	14	41
OEDICEROTIDAE		
Monoculodes cfr. gibbosus Chevreux, 1888	1	1
Monoculodes carinatus (Bate, 1857)	1	1
Perioculodes longimanus (Bate and Westwood, 1868)	3	3
Pontocrates altamarinus (Bate and Westwood, 1862)	1	1
Westwoodilla rectirostris (Della Valle, 1892)	5	17
PHOXOCEPHALIDAE		
Harpinia antennaria Meinert, 1893	1	1
Harpinia crenulata Boeck, 1871	6	9
Harpinia dellavallei Chevreux, 1910	6	24
Metaphoxus fultoni (Scott, 1896)	3	3
Metaphoxus pectinatus (Walker, 1896)	1	1
PONTOPOREIDAE		
Bathyporeia guilliamsoniana (Bate, 1856)	4	27
Bathyporeia pseudopelagica Bellan-Santini and Vader, 1988	4	9
UROTHOIDAE		
Urothoe elegans Bate, 1857	13	107
Urothoe pulchella (A. Costa, 1853)	3	9
PHTISICIDAE		

rank correlation index (Daget, 1979) was used to measure the similarity, while hierarchical grouping was performed by means of the Lance and Williams (1967) aggregation algorithm (groups of average link).

Differences in sedimental data of station groups resulting from the cluster analysis were tested by means of the *t* of Student and the *F* of Fisher tests (Sokal and Rohlf, 1969). The product-moment correlation coefficients (Sokal and Rohlf, 1969) between the most abundant species and sedimental data were computed in order to test the distribution of the most abundant species in different sediment types.

RESULTS

1- Physicol-chemical data

Sediment characteristics are shown in Table II. Generally, along the depth gradient the shallowest samples are of sandy sediments with high values of C/N ratio. Sandy-muddy sediments are present at low depth in the northern part of the study area, both on the Adriatic and the Jonian Sea. In these areas the C/N value is low. At intermediate depth, the gravel fraction and the amount of calcium carbonate are generally the highest, and the C/N ratio is low. Biogenic bottoms, deeper than the sandy ones are more abundant in the southern sampled area. The deepest stations are composed of muddy sediments generally with a low value of C/N ratio.

2- Amphipod assemblages

Concerning the faunal data, a total of 919 individuals belonging to 60 species were collected (Table III). Families have been listed according to

Table IV - Significative values of *t* and *F* tests ($p < 0.05$) computed on sedimental data of station groups resulting from cluster analysis. /*Résultats des tests t et F (p < 0.05) calculées sur des données sédimentologiques des groupes de stations résultant d'analyses d'agrégation.*

group comparison	DEPTH (m)	GRAVEL %	SAND %	SILT %	CLAY %	C/N	$CaCO_3$ %
I-II							
T	3.14	2.22	7.05	4.09	9.23	-	2.29
F	2.06	-	1.20	1.52	1.80	-	-
Iab-Ic							
T	2.36	6.91	-	-	-	-	-
F	1.18	1.93	-	-	-	-	-
Ia-Ib							
T	-	-	-	-	-	2.58	-
F	-	-	-	-	-	2.37	-
IIa-IIb							
T	3.26	-	1.40*	-	-	-	-
F	1.95	-	1.88	-	-	-	-

*p < 0.01

Table V - Summary of significant product-moment correlation coefficients ($p < 0.05$) between abundance distribution of the most important species and sedimental parameters./ *Valeurs des corrélations significatives (p < 0.05) entre les données d'abondance des espèces les plus importantes et les données sédimentologiques.*

Species	GRAVEL %	SAND %	SILT %	CLAY %	C %	N %	$CaCO_3$ %
A. brevicornis	0	+ 0.33	0	0	0	0	- 0.42
A. sarsi	0	+ 0.36	0	- 0.32	0	0	- 0.43
A. typica	0	+ 0.34	0	- 0.31	0	0	- 0.37
C. runcicorne	0	+ 0.31	0	0	0	0	- 0.33
B. guilliamsoniana	0	+ 0.34	0	0	+ 0.41	0	0
H. massiliensis	0	+ 0.35	0	0	0	0	0
L. costae	+ 0.84	0	0	0	+ 0.36	+ 0.47	0
M. schmidtii	0	- 0.51	+ 0.40	+ 0.51	0	0	0
U. elegans	0	+ 0.41	- 0.34	- 0.36	0	0	0
P. longicaudata	0	+ 0.32	0	0	0	0	- 0.38

the systematic revision proposed by Ruffo (in press) for the Mediterranean Amphipods. Most species are present with a very low number of individuals, whereas only a few, such as *Urothoe elegans* Bate, *Photis longicaudata* Bate and Westwood, *Maera schmidtii* Stephensen, *Lysianassa costae* Milne Edwards, *Lembos angularis* Ledoyer, *Corophium runcicorne* Della Valle, *Ampelisca typica* Bate, and *Ampelisca diadema* Costa, have a high density contributing 54 % of the total abundance. Species richness and abundance are higher in the shallowest stations located above 40 m depth (50 species and 809 individuals collected in 28 stations) than in the deepest stations which are mainly composed of very few highly dominant species (26 species and 111 individuals found in 24 stations).

The cluster analysis on faunal data (42 species and 42 stations were selected) revealed the presence of two main groups of stations (Figure 2). The first (I) is mostly composed of stations located above 75 m depth with sandy or detritic bottoms, with the exception of stations 2C and 42A. These stations belong to this group, even though they are characterized by a low sand content in sediments. The other group (II) includes many stations with a high level of silt and clay in sediments in spite of their depth. Although stations 40A and 22C are composed of sandy sediments, they are included in the last group.

In group I, three subgroups (Ia, Ib, Ic) could be identified for a similarity level of 30 %, whereas only two are present in the second group (IIa, IIb). Values of *t* and *F* tests indicate a significant difference on sedimental data between the groups of stations resulting from the analysis on faunal data (Table IV). Concerning the first group, the subgroup Ia includes stations of fine sand with a generally high value of Carbon in sediments, with the exception of station 2C. In subgroup (Ia) dominant species are : *U. elegans, P. longicaudata, A. typica, C. runcicorne, L. angularis, Ampelisca brevicornis* Costa, *Bathyporeia guilliamsoniana* Bate, and *Ampelisca pseudospinimana* Bellan-Santini and Kaim Malka. Many of these species are significantly correlated to the sand

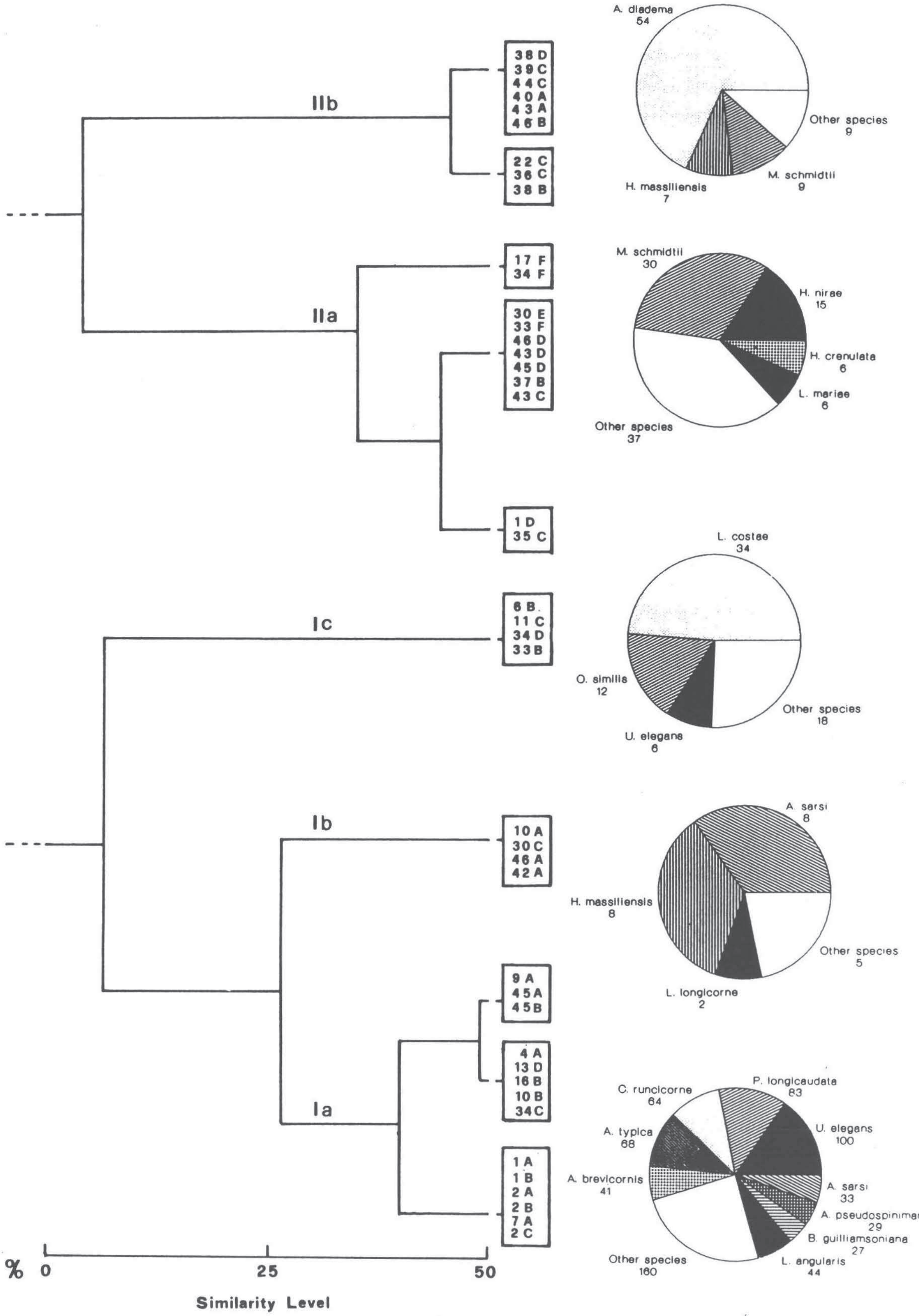

Figure 2 - Clusters resulting from normal classification analysis (Q-mode) using Spearman Similarity Index. Pie charts show the abundance percentage composition in each subgroup of sampling stations (Ia, Ib, Ic, IIa, IIb). Numbers under the names of species indicate the abundance of specimens. / *Dendrogrammes résultant d'analyses d'agrégation en mode Q par l'indice de similarité de Spearman. Les diagrammes circulaires montrent la composition du pourcentage d'abondance de chaque sous-groupe de stations de prélèvements. Les chiffres au-dessous des noms d'espèces indiquent l'abondance des individus.*

fraction (Table V), and are reported in literature as characteristic of fine-sand assemblages (Fébvre Chevalier 1969 ; Massé, 1972 ; Drago *et al.*, 1978 ; Nodot *et al.*, 1984). In station 2C, in spite of the amount of silt and clay fractions, only two individuals were collected, belonging to the species *Photis longicaudata* and *Urothoe elegans*. As reported by the pie chart (Figure 2) these stations which belong to subgroup 1A are characterized by a high abundance of species and individuals (34 species and 649 individuals).

The second subgroup (Ib) is composed of those fine-sandy stations with a high value of C/N ratio owing to a low value of Nitrogen in sediments, with the exception of station 42A ; there the silty fraction is dominant, even if it is located in shallow waters. The stations belonging to group Ib are characterised by the lowest abundance of species and individuals (23 individuals belonging to 8 species). Dominant species are *Ampelisca sarsi* Chevreux, *Hippomedon massiliensis* Bellan-Santini, and *Lepidepecreum longicorne* Bate and Westwood.

The last subgroup (Ic) includes stations of sandy-detritic bottoms deeper than sandy ones. Dominant species are *L. costae, Orchomene similis* Chevreux, *U. elegans*, and *Leucothoe pachycera* Della Valle, which have been frequently reported for detritic and coarse bottoms (Marques and Bellan-Santini, 1985 ; Bellan-Santini and Marques, 1984 ; Drago *et al.*, 1978). As shown by the pie chart (Figure 2) a high abundance of *L. costae* and *O. similis* was recorded in this station with low species richness (9 species and 70 individuals). Whereas *U. elegans* is a sabulicolous species present also in group Ia, *L. costae* is higly correlated to the gravel fraction (Table V).

In the second group of stations, the first subgroup (IIb) includes shallow sampling stations located near the outlet of the northern rivers between 10 m and 50 m depth. Here sandy and muddy fractions in sediments are equally important. Dominant species are *A. diadema, H. massiliensis*, and *M. schmidtii*. *A. diadema* is typical of mixed bottoms, while *H. massiliensis* and *M. schmidtii* are reported for sandy and muddy bottoms respectively (De Gaillande, 1968 ; Nodot *et al.*, 1984 ; Falciai and Spadini, 1985). In fact, *H. massiliensis* is present also in sandy stations while *M. schmidtii* is correlated to silt and clay fractions (Table V).

The last subgroup (IIa) is composed of those sampling stations (more than 20 m depth) where silt and clay are dominant fractions in sediments. Dominant species are *Haploops nirae* Kaim Malka and *M. schmidtii*. In spite of their depth, stations 17F and 34F are the most different within this group because of the presence of a high level of sand. Here the species *H. nirae* has the highest abundance.

DISCUSSION

The importance of sediment texture on the distribution of soft-bottom benthic species is frequently reported in the literature (Sanders, 1956, 1958 ; Gray, 1981). According to the classical view, and in the case studied above, the distribution of amphipod species is principally due to sediment texture. Two main groups of species could be identified for sandy and muddy bottoms respectively.

From present data, amphipods are more abundant and diversified in sandy bottoms than in muddy ones. In fact, sandy bottoms have the highest values of abundance and species richness. Here the most important factor affecting species distribution is the amount of calcareous debris which improves sediment heterogeneity. Bottoms with a high level of sediment heterogeneity such as those of biodetritic origin, are also characterized by the greatest amount of living matter, assessed as the amount of Nitrogen. Despite that, and although the amphipod community has a high number of individuals, it does not appear rich in species. In fact, *L. costae* and *O. similis*, reported as characteristic of detritic assemblages, are quite dominant.

Moreover, two horizons could be identified in fine sand community as suggested by Massé (1972) : the shallow horizon being an impoverishment of the deep one probably owing to water movement. The shallowest stations have a low value of organic matter in sediment. This affects the bottom fauna which is represented by few species (*Hippomedon massiliensis, Lepidepecreum longicorne)* typically reported for coarse sandy bottoms exposed to water movement (Marques and Bellan-Santini, 1985 ; Drago *et al.*, 1978).

The deepest fine-sandy bottoms are the best structured from the amphipodological point of view. Most of the species recorded are generally considered characteristic of the fine well sorted sand community (Marques and Bellan-Santini, 1985).

All species mentioned above tend to disappear in muddy bottoms where they are replaced by *A. diadema, H. crenulata, L. mariae, M. schmidtii* and *H. nirae*. Where the muddy bottoms are located in shallow waters, such as near the outlet of rivers, these species typically reported for muddy bottoms, are associated with *H. massiliensis* also reported for coarsy or mixed bottoms (Falciai and Spadini, 1985).

In muddy bottoms low species richness was detected, while the high abundance is due to the species *A. diadema*, in the first subgroup, and *H. nirae* and *M. schmidtii* in the second.

CONCLUSION

In conclusion, along the Apulian coast, the shallow sandy bottoms are characterized by *U. elegans, A. brevicornis, A. sarsi, A. typica, C. runcicorne, B. guilliamsoniana, P. longicaudata* and *H. massiliensis* which are positively correlated to the amount of sand. At intermediate depth a community of detritic bottoms has been identified. This is characterized by *L. costae*, positively correlated to the gravel fraction and *O. similis*. Here the influence of water currents acts as a selective factor causing an impoverishment in species composition and a high level of dominance. The amount of finest sediments is another selective factor for amphipod communities. In fact, in muddy bottoms the lowest values of species richness and abundance were recorded. Characteristic species of deeper muddy bottoms are *M. schmidtii*, positively correlated to the finest fractions of sediments, and *H. nirae*. In shallower muddy bottoms where a sandy fraction is present the most abundant species is *A. diadema* typically reported as *"mixticolous"* species.

ACKNOWLEDGEMENTS

This research was supported by the ENEA (Centro Ricerche Energia Ambiente) who carried out the analysis of sediments. The authors wish to thank Dr. C. N. Bianchi for providing amphipod samples and for useful information, Dr G.D. Ardizzone and Prof. R. Argano for their critical reading of the manuscript and for their suggestions.

REFERENCES

Bedulli D., C.N. Bianchi, C. Morri, G. Zurlini, 1986 - Caratterizzazione biocenotica e strutturale del macrozoobenthos delle coste pugliesi. In *: Indagine ambientale del sistema marino costiero della regione Puglia.* M. Viel , G. Zurlini (eds.), ENEA, Roma, pp : 227-255.

Bellan-Santini D., M. Ledoyer, 1973 - Inventaire des Amphipodes Gammariens récoltés dans la région de Marseille. *Tethys*, **4** (4) : 899-934.

Bellan-Santini D., G. Karaman, G. Krapp-Schickel, M. Ledoyer, A. Myers, S. Ruffo, A. Schrecke, 1982 - The Amphipoda of the Mediterranean. Part 1. Gammaridea (Acanthonotozomatidae to Gammaridae). *Mém Inst. océanogr. Monaco*, **13** : 1-364.

Bellan-Santini D., G. Diviacco, G. Krapp-Schickel, A. Myers, R. Ruffo, 1989 - The Amphipoda of the Mediterranean. Part 2. Gammaridea (Haustoridae to Lysianassidae). *Mém Inst. océanogr. Monaco*, **13** : 365-576.

Bellan-Santini D., J.C. Marques, 1984 - Contribution à l'étude des Amphipodes des côtes du Portugal. *Cienc. Biol. (Écol. Syst.)*, **5** : 131-149.

Bourcier M., C. Nodot, A. Jeudy De Grissac, J. Tiné, 1979 - Répartition des biocénoses benthiques en fonction des substrats sédimentaires de la rade de Toulon. *Tethys*, **9** : 103-112.

Cecchini C., P. Parenzan, 1934 - Anfipodi del Golfo di Napoli. *Pubbl. Staz. zool. Napoli*, **14** (2) : 155-251.

Cocito S., S. Fanucci, I. Nicolai, C. Morri, C.N. Bianchi, 1990 - Relationship between trophic organization of benthic communities and organic matter content in Tyrrhenian Sea sediments. *Hydrobiologia*, **207** : 53-60.

Colognola R., L. Labinchi, E. Fresi, L.A. Chessa, 1984 - Distribuzione degli Echinodermi nei fondi mobili dragabili del golfo di Salerno : aspetto invernale. *Nova Thalassia*, **6** suppl.

Daget J., 1979 - *Les modèles mathématiques en écologie.* Collection d'Écologie, **8**. Masson, Paris : 145-154.

Damiani V., C.N. Bianchi, O. Ferretti, D. Bedulli, C. Morri, M. Viel, G. Zurlini, 1988 - Risultati di una ricerca ecologica sul sistema marino costiero pugliese. *Thalassia salent.*, **18** : 153-170.

De Gaillande D., 1968 - Monographie des peuplements benthiques d'une calanque des côtes de Provence. Port Miou. *Recl Trav. Stn mar. Endoume*, **44** : 358-401.

Drago, N., G. Albertelli, M. Cattaneo, 1978 - Osservazioni faunistiche sul benthos dell'isola di Capraia. *Ann. Mus. civ. Stor. nat. Giacomo Doria*, **82** : 72-77.

Eleftheriou, A., D.J. Basford, 1989 - The macrobenthic infauna of the offshore northern North Sea. *J. mar. biol. Assoc. U.K.*, **69** : 123-143.

ENEA, 1986 - *Indagine ambientale del sistema marino costiero della Regione Puglia. Elementi per la definizione del piano delle coste.* ENEA S. Teresa, La Spezia , 277 pp.

Falciai L., V. Spadini, 1985 - Anfipodi del piano infralitorale del Tirreno Centro-Settentrionale. *Atti Soc. Tosc. Sci. nat. Mem.* Ser. B, **2** : 145-163.

Fébvre Chevalier C., 1969 - Étude bionomique des substrats meubles dragables du Golfe de Fos. *Tethys*, **1** : 421-476.

Focardi S., E. Fresi, M.C. Gambi, 1982 - Analisi della distribuzione degli Echinodermi dei fondi mobili di due aree del Tirreno : un'applicazione di tecniche multidimensionali. *Natur. Sicil.*, **4**, suppl. 3 : 531-540.

Fresi E., M.C. Gambi, S. Focardi, F. Baldi, R. Bargagli, L. Falciai, 1983 - Benthic community and sediment types : a structural analysis. *Mar. Ecol. P. s.z.u*, **4** : 101-121.

Gambi M.C., E. Fresi, 1981 - Ecology of soft-bottom macrobenthos along the coast of Southern Tuscany (parco naturale della Maremma). *Rapp. P.-v. Réun. CIESM*, **27**(2) : 123-125.

Gambi M.C., A. Giangrande, 1982 - Gruppi trofici dei Policheti di fondo mobile : un esempio alla foce del Tevere. *Boll. Mus. Ist. biol. Univ. Genova*, **50** suppl. : 202-207.

Gambi M.C., A. Giangrande, 1986 - Distribution of soft-bottom Polychaetes in two coastal areas of Tyrrhenian Sea (Italy) : structural analysis. *Estuar. coast. Shelf Sci.*, **23** : 847-862.

Gambi M.C., A. Giangrande, E. Fresi, 1983 - I Policheti dei fondi mobili del Golfo di Salerno : ipotesi di un modello di distribuzione generale. *Nova Thalassia*, **6** (83/84 suppl.) : 575-583.

Giangrande A., M.C. Gambi, 1982 - Distribuzione dei Policheti nei fondi mobili della Rada di Augusta (Sicilia). *Boll. Mus. Ist. biol. Univ. Genova*, **50** suppl. : 218-222.

Gray J.S., 1981 - *The ecology of marine sediments.* Cambridge Studies in Marine Biology, **2,** 183 pp.

Intès A., P. Le Loeuff, 1986 - Les Annélides polychètes de Côte d'Ivoire. 4. Relations faune-sédiments. *Océanogr. trop.*, **21** : 53-88.

Laborda Navia, A.J., 1983 - Anfipodos intermareales sobre sustrato blando en la Playa de Covas (o del El Grallal), Ria de Vivero (Lugo). Actas I Congr. Iberico Entomol. Leon, June 1983 : 369-378.

Lance G.N., W.I. Williams, 1967 - A general theory of classificatory sorting strategies. I. Hierarchical systems. *Comput. J.*, **9** : 373-380.

Ledoyer M., 1968 - Écologie de la faune vagile des biotopes méditerranéens accessibles en scaphandre autonome. 4. Synthèse de l'étude écologique. *Recl Trav. Stn mar. Endoume*, **44** : 125-295.

Ledoyer M., 1969 - La faune vagile des sables fins des hauts niveaux (SFHN). Signification bionomique de ce biotope vue sous l'angle de la faune vagile. *Tethys,* **1** : 275-280.
Ledoyer M., 1977 - Contribution à l'étude de la faune vagile profonde de la Méditerranée N-O. 1. Les Gammariens. *Boll. Mus. civ. Stor. nat. Verona,* **4** : 321-421.
Marques J.C., D. Bellan-Santini, 1985 - Contribution à l'étude systématique et écologique des Amphipodes des côtes du Portugal. Premier inventaire des espèces. *Cienc. biol. (Ecol. Syst.),* **5** : 299-353.
Martí A., I.M. Guier, I.M. Garcia-Carrascosa, 1990 - Amphipods and benthic biocenosis on the coasts of Alboraya-Albuixech (Spain). *Rapp. P.-v. Réun. CIESM,* **32** (1) : 16.
Massé H., 1972 - Quantitative investigations of sand bottom macrofauna along the Mediterranean north-west coast. *Mar. Biol.,* **15** : 209-220.
Maze R.A., A.J. Laborda, 1986 - Some aspects on the distribution of the intertidal amphipodos of the Playa de Area Longa, Ria del Barquero, Lugo (NW Spain). Actas 8 Jornadas A e E, Sevilla : 156-166.
Mirza F.B. , J.S. Gray, 1981 - The fauna of benthic sediments from the organically enriched Oslofjord, Norway. *J. exp. mar. Biol. Ecol.,* **54** : 181-207.
Nodot C., M. Bourcier, A. Jeudy De Grissac, S. Heusner, J. Régis, J. Tiné, 1984 - Répartition des biocoenoses benthiques en fonction des substrats sédimentaires de la rade de Toulon (France). 2. La Grande Rade. *Tethys,* **11** : 141- 153.
Picard J., 1965 - Recherches qualitatives sur les biocénoses marines des substrats meubles dragables de la région de Marseille. *Recl Trav. Stn mar. Endoume,* **52** : 1-60.
Picard C., 1971 - Les peuplements de vase au large de Fos. *Téthys,* **3** (3) : 569-618.
Relini G., G.D. Ardizzone, A. Belluscio, 1986 - Le biocenosi bentoniche costiere delle Cinque Terre (Mar Ligure Orientale). *Boll. Mus. Ist. biol. Univ. Genova,* **52** suppl. : 163-195.
Ruffo S., (Ed.), 1993 - The Amphipoda of the Mediterranean. Part 3. Gammaridea (Melphidippidae to Talitridae), Ingolfiellidea, Caprellidea. *Mém Inst. océanogr. Monaco,* **13** : 577-813.
Ruffo S., (Ed.), in press - The Amphipoda of the Mediterranean. Part 4. *Mém Inst. océanogr. Monaco,* **13.**
Russo G.F., E. Fresi, 1983 - Analisi strutturale del popolamento a Molluschi nei fondi mobili del golfo di Salerno : aspetto invernale. *Boll. Soc. Nat. Napoli,* **89** : 33-45.
Russo G.F., E. Fresi, M. Scardi, 1984 - Il popolamento a Molluschi dei fondi mobili del Golfo di Salerno : analisi strutturale in rapporto al trofismo. *Oebalia,* **11**N.S. : 339-348.
Salen-Picard C., 1987 - Valeurs centrales (analyse de gradient) et délimitation de groupes d'espèces en fonction des facteurs du milieu. *Oceanologica Acta,* **10** : 217-222.
Sanders H.L., 1956 - Oceanography of Long Island Sound, 1952-54. The Biology of marine bottom communities. *Bull. Bingham oceanogr. Colln,* **15** : 345-414.
Sanders H.L., 1958 - Benthic studies in Buzzards Bay. 1. Animal-sediment relationship. *Limnol. Oceanogr.,* **3** : 245-258.
Scipione M.B., 1989 - Il comportamento trofico dei Crostacei Anfipodi in alcuni sistemi bentonici costieri. *Oebalia,* **15** (1) N. S.: 249-260.
Scipione M.B., M.C. Buia, M.C. Gambi, M. Lorenti, G. Russo, V. Zupo, L. Mazzella, 1989 - Prime indagini sulle comunità bentoniche in un'area del Golfo di Napoli soggetta a disturbo antropico. *Nova Thalassia,* **10** suppl. 1 : 557-565.
Somaschini A., G.D. Ardizzone, 1991 - Benthos di fondo mobile delle isole pontine : 2. Anfipodi. *Oebalia,* **17** : 417-419.
Sokal R.R., F.J. Rholf, 1969 - *Biometry.* Freeman W.H. and Company, New York, 859 pp.
Viel M., V. Damiani, M. Setti, 1986a - Caratteristiche granulometriche e composizione mineralogica dei sedimenti della piattaforma pugliese. In : *Indagine ambientale del sistema marino costiero della regione Puglia,* M. Viel, G. Zurlini (eds.), ENEA, Roma, pp 127-147.
Viel M., S. De Rosa, V. Damiani, G. Zurlini, 1986b - Geochimica degli elementi in traccia e forme del fosforo nei sedimenti della piattaforma pugliese. In : *Indagine ambientale del sistema marino costiero della regione Puglia,* M. Viel, G. Zurlini (eds.), ENEA, Roma, pp 149-169.
Wentworth C.K., 1922 - A scale of grade and class terms for clastic sediments. *J. Geol.,* **30** : 377-392.

Reçu en juin 1993 ; accepté en mars 1994.
Received June 1993 ; accepted March 1994.