Internat. Rev. Hydrobiol.	83	1998	5–6	461–477

A. PAPAZACHARIAS[1], A. KOUKOURAS[1], T. KEVREKIDIS[2] and E. VOULTSIADOU[1]

[1] Aristoteleio University of Thessaloniki, Department of Zoology, 54006 Thessaloniki, Greece
[2] Democritus University of Thrace, Department of Education-Primary level, 68100 Alexandroupoli, Greece

Infra- and Circalittoral Soft Substratum Macrofaunal Assemblages of Kavala Gulf (Aegean Sea)

key words: Macrozoobenthic assemblages, soft substratum, infralittoral zone, circalittoral zone, Mediterranean, Aegean Sea

Abstract

Five macrobenthic assemblages of the infralittoral and circalittoral zones located in the Gulf of Kavala, North Aegean, are described: (i) the assemblage of gravely sand with *Parvicardium roseum* and *Clausinella brogniartii*, (ii) the assemblage of sandy silt with *Loripes lacteus* and *Nephthys hombergii*, (iii) the clayey silt assemblage with *Terebellides stroemi* and *Sternaspis scutata*, (iv) the sandy silt assemblage with *Amphiura chiajei* and (v) the assemblage of silt with *Labioleanira yhleni*, the latter being described for the first time. Their composition is statistically tested, discussed in relation to abiotic factors, and compared with that of the corresponding assemblages from the Aegean and other Mediterranean and Atlantic areas.

1. Introduction

The Mediterranean Sea is known to represent a separate section of the Atlanto-Mediterranean zoogeographical subregion, supporting a considerable number of endemic species. In the Mediterranean basin, the composition of the fauna, and especially the benthic fauna, varies getting impoverished from the west to the east (e.g. EKMAN, 1967; POR and DIMENTMAN, 1989; KOUKOURAS *et al.*, 1995). This qualitative differentiation of the benthic fauna is reflected by the qualitative and quantitative composition of the benthic assemblages (e.g. GILAT, 1964; GALIL and LEWINSOHN, 1981; KOUKOURAS and RUSSO, 1991). Consequently, the knowledge of the diversity in the composition of the various benthic assemblages of the eastern Mediterranean, supplies with information of local as well as of more general interest, when this information is compared with that existing from the western basin of the Mediterranean and the adjacent area of the Atlantic coast.

The bulk of the research on the benthic asemblages of the soft substrate has, undoubtly, been carried out in the western Mediterranean (e.g. PICARD, 1965; GUILLE, 1970; DESBRUYÉRES *et al.*, 1973; ROS *et al.*, 1985).

The information on the qualitative and quantitative composition of the macrobenthic infralittoral and circalittoral soft substrate assemblages in the Eastern Mediterranean (Levantine Sea and Aegean Sea) is still very limited (e.g. PÉRÈS and PICARD, 1958; TCHUKHTCHIN, 1963; GILAT, 1964; VAMVAKAS, 1970, 1971; GALIL and LEWINSOHN, 1981). More specially, regarding the South Aegean, there is very little but recent information, included in the publications by KARAKASSIS (1991), KARAKASSIS and ELEFTHERIOU (1997).

On the assemblages of the North Aegean Sea, which are considered similar with those of the corresponding areas of the NW Mediterranean (PÉRÈS, 1967), the scarse available information is included in the older publications by KISSELEVA (1961, 1963, 1983), MAKKAVIEVA (1963), KISSELEVA and TCHUKHTCHIN (1965) and GELDIAY and KOCATAS (1972) and the more recent ones by ZARKANELLAS (1977), ZARKANELLAS and KATTOULAS (1982), BOGDANOS and SATSMADJIS (1983), DIAPOULIS and BOGDANOS (1983), KOUKOURAS and RUSSO (1991), DOUNAS and KOUKOURAS (1992), GOUVIS and KOUKOURAS (1993) and SIMBOURA *et al.* (1995).

In order to estimate the composition of macrobenthic infralittoral and circalittoral soft substrate assemblages in the North Aegean Sea, as well as the possible impact of pollution on it, samplings were carried out, since 1976, in the Thermaikos, Strymonikos and Kavala Gulf (KATTOULAS *et al.*, 1980). Thermaikos Gulf receives larger amounts of industrial effluents and domestic sewage than the two others do; information on the composition of its assemblages and the impact of pollution on them have been given by KOUKOURAS *et al.* (1982) and ZARKANELLAS and KATTOULAS (1982). Strymonikos Gulf is the least polluted area of the three; information on the corresponding assemblages has been given by DOUNAS (1986) and DOUNAS and KOUKOURAS (1992). Kavala Gulf receives a moderate load of pollutants, and up to now, only preliminary data on the corresponding assemblages have been published by KOUKOURAS *et al.* (1982). In the present paper, the results of this research, as far as the Kavala Gulf is concerned are given.

The main goals of this study are (i) to give a detailed description of the infralittoral and circalittoral macrobenthic assemblages of the Kavala Gulf, (ii) to investigate their relationships with the environmental characteristics of the area, including pollution, (iii) to provide information on their distribution, and (iv) to compare them with the corresponding assemblages of other Atlanto-Mediterranean areas.

2. Material and Methods

Forty-three sampling stations were selected in Kavala Gulf (Fig. 1). The number of the sampling stations was selected in order to cover sufficiently the various sediment types that had been estimated in a preliminary survey, and the main areas of pollutant discharge, namely the industrial outfall (N. Karvali) and the sewage outfall (Kavala); the number of the stations is sufficient in relation to the area of the Gulf, not exceeding the 220 km^2. At the stations marked with a triangle on the transects, sampling was repeated seasonally in two successive years. In addition to the faunal samples, sediment and bottom water samples were taken at each station. Sediment temperature, at a depth of 1 cm, and water salinity near the bottom were measured. Sediment particle size analysis and estimation of organic carbon were made according to the methods described by BUCHANAN (1984).

For faunal analyses, 2 replicate samples of the substrate were collected at each station in September 1976, using a van Veen grab (total sampling area 0.2 m^2 and sediment volume 40 dm^3 approximately). Samples were sieved on a 1 mm mesh size. After being removed from the sediment, the fauna of the two replicate samples was mixed in order to have a more representative sample from each station.

Cluster analysis was performed to determine the similarity among samples (Q-analysis). The Bray-Curtis similarity coefficient was used on log-transformed data [log (a + 1)] (SANTOS and BLOOM, 1983). Hierarchical clustering of samples was achieved using the group-average sorting strategy (LANCE and WILLIAMS, 1967). The biological indices technique was used to classify the species for each of the different macrobenthic assemblages established (GUILLE, 1970; VOULTSIADOU-KOUKOURA *et al.*, 1987; etc.). According to these methods, the biological index value of a species in an assemblage is the total of the ranges it occupies in all the samples taken from the assemblage. The range of a species in a sample is a result of its value of dominance in relation to the values of dominance of the remaining species of the assemblage. Species diversity (H′) was calculated by Shannon's formula (SANDERS, 1968; PIELOU, 1969). Species richness (D) was computed by the formula $s - 1/\ln N$ (MARGALEF, 1957) and evenness (J) was measured by the formula $H'/\log_2 S$ (PIELOU, 1969). Additionally, detrended correspondence analysis was performed using the programme DECORANA (HILL, 1979). Correlation coefficient, one-way analysis of variance and least-significant difference method (L.S.D) were performed on log transformed data ($x = \ln x$).

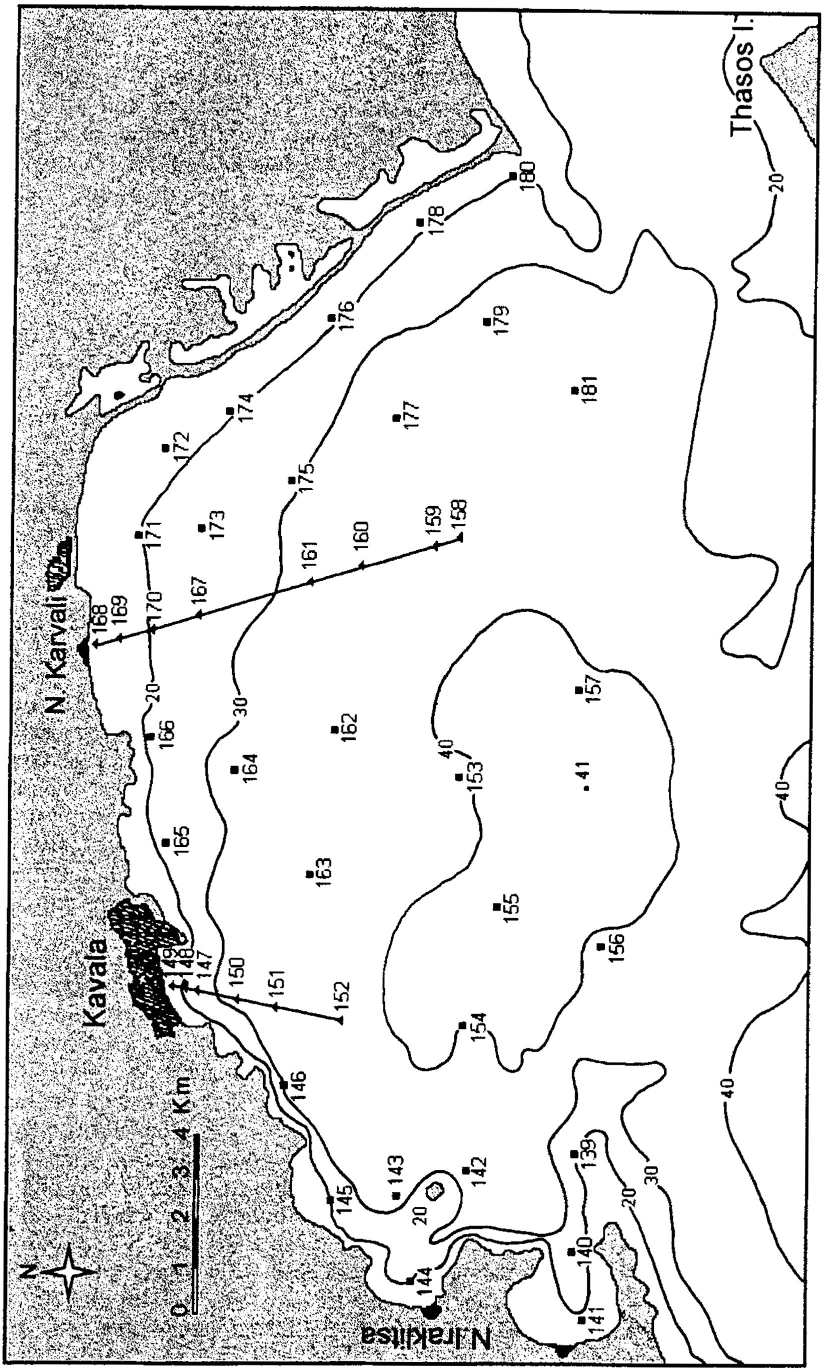

Figure 1. Map of Kavala Gulf showing the sampling stations and depth contours in meters.

3. Results

3.1. Environmental Parameters

Measurements of water depth, temperature, median particle diameter (Md), percentage of the silt-clay fraction (<63 μm), organic carbon content of the sediment, and water salinity near the bottom are presented in Table 1. The depth varied between 6 and 49 m, temperature between 16 and 22.5 °C, Md was 4–1741 μm, silt-clay fraction 3.0–98.3%, organic carbon 0.15–2.79% and salinity 36.0–37.9‰.

3.2. The Fauna

A total of 15,350 individuals belonging to 301 macrobenthic species were examined, coming from the 43 sampling stations. Polychaetes predominated with 100 species (33.2%). Crustaceans was the second dominant taxon with 92 species (30.6%), 54 of which were amphipods (17.9%), 32 decapods (10.6%), and 6 (2.1%) belonged to other crustacean groups. Molluscs were represented by 62 species (20.6%): 45 bivalves (14.9%), 12 gastropods (4.0%) and 5 other species (1.7%). Echinoderms were represented by 24 species (8.0%) and all the other groups, namely Cnidaria, Turbellaria, Nemertea, Bryozoa, Phoronida, Sipuncula, Echiura and Chordata by 23 species (7.6%). Table 1 shows the total number of species, abundance, diversity, richness and evenness for each station.

3.3. Benthic Assemblages

The hierarchical classification of the sampling stations on the basis of similarity in faunal composition is shown in the dendrogram of Fig. 2. At a similarity level of approximately 30%, 5 station groups were distinguished, corresponding to 5 distinct assemblages; their distribution in the area of the gulf is given in Fig. 3. The mean benthic ecosystem parameters for the five station groups are given in Table 2, while Table 3 includes the mean dominances and mean abundances of the most dominant species in each station group (assemblage). Table 4 ranks the top ten species of each station group (assemblage), according to their biological index, and indicates their ranking in the remaining station groups (group I does not appear since it consists of only 2 stations).

Group I, as mentioned above, includes only 2 stations (Fig. 1, 2); those stations are characterized by very coarse sediment (Tables 1, 2), consisting of gravels and coarse biogenic detritus, by low values of organic carbon in the sediment, high H′, J and D and the dominance of the bivalves *Parvicardium roseum* and *Clausinella brongniartii* (Table 3).

Group II accounts for 4 stations located either in the port of Kavala (st. 148) or near the phosphate industry of Nea Karvali (Fig. 1). Their depth range is 6–17 m and the sediment varies from silt to very fine sand (Tables 1, 2). This assemblage is characterized by a low number of species and low values of H′, J and D (Table 2). Most dominant species are the sipunculan *Aspidosiphon muelleri* (= *A. kovaleskii*), the bivalves *Loripes lacteus* and *Tellina nitida* and the polychaete *Nephtys hombergii* (Table 3), but the top ranked species are *N. hombergii* and *L. lacteus* (Table 4).

Group III accounts for 4 stations located at the deepest (43–49 m) area of the gulf (Fig. 1, 3; Table 1). Sediment is very fine to medium silt, and the silt-clay fraction is 96.7–98.3%. As normally expected, in these stations, the lowest temperature and the highest organic carbon values were measured (Tables 1, 2). The assemblage found is characterized by low macrobenthic abundance (Tables 1, 2) and the dominance of 5 polychaete species (Table 3); the species *Terebellides stroemi* was top ranked (Table 4).

Table 1. Major environmental parameters, number of species (NS), abundance and diversity indices (H′, J, D) at the sampling stations.

Stations	Depth (m)	Water salinity (‰)	Sediment				NS (/0.2 m²)	Abundance (/0.2 m²)	H′	J	D
			Temperature (°C)	Organic carbon (%)	Md (μm)	Silt & clay fraction (%)					
139	25.5		19.0	0.38	716	3.0	31	284	4.64	0.94	5.38
140	25.5		19.0	2.31	22	83.2	35	343	3.08	0.60	5.82
141	16		22.0	0.15	16	93.1	42	844	2.94	0.55	6.10
142	35		17.0	2.54	7	88.8	27	66	4.29	0.90	6.21
143	30		20.0	1.00	1741	20.3	63	213	5.24	0.87	11.82
144	16		21.5	2.16	25	75.3	51	360	3.66	0.64	8.48
145	27		18.5	1.99	39	60.9	48	313	4.25	0.76	8.17
146	29		19.0	2.79	18	74.7	37	284	3.02	0.58	6.35
147	24	37.6	20.5	1.08	33	65.8	87	928	4.48	0.70	12.54
148	11	36.0	19.5	2.28	48	55.6	9	127	1.69	0.53	1.65
149	22	37.2	18.5	1.69	70	41.8	69	780	3.93	0.64	10.38
150	29.5	36.6	17.0	1.72	29	89.6	38	265	3.53	0.67	6.86
151	32	37.5	17.0	2.37	19	95.2	28	138	2.77	0.57	5.67
152	38	37.3	16.5	2.52	4	97.6	24	60	3.67	0.84	4.99
153	38.5		16.5	2.28	43	55.6	38	493	3.04	0.58	5.96
154	44		16.0	2.45	15	98.1	16	43	3.72	0.93	4.01
155	43		16.0	2.21	4	96.9	13	23	3.50	0.95	3.94
156	49		16.0	2.10	5	98.3	11	28	3.21	0.89	3.34
157	48		16.5	2.36	4	96.7	12	24	3.33	0.93	3.56
158	39.5	37.6	16.5	1.59	4	91.1	17	65	3.58	0.88	3.96
159	38.5	37.9	16.5	1.41	5	94.7	18	51	3.55	0.85	4.37
160	34	37.7	17.0	1.46	5	90.5	13	47	3.15	0.85	3.13
161	29.5	37.3	17.0	1.63	15	67.1	18	115	1.80	0.43	3.57
162	36		16.5	2.43	41	84.6	31	216	3.24	0.65	5.59
163	38		16.5	2.40	5	97.4	6	10	2.50	0.97	2.40
164	32		17.0	2.48	5	96.4	27	94	4.22	0.89	5.72
165	17		22.5	1.89	66	44.8	57	4183	2.47	0.42	7.54
166	16.5		22.0	0.66	129	19.7	62	1371	3.42	0.57	8.45
167	25	37.4	20.0	2.29	29	92.4	18	113	2.66	0.64	3.60
168	6	36.7	21.0	1.29	100	7.4	15	50	3.14	0.80	3.58
169	11.5	36.9	21.0	0.99	69	43.4	4	19	1.87	0.94	1.02
170	17	36.4	21.0	2.04	19	90.7	19	128	1.97	0.46	3.75
171	17.5		22.0	1.10	25	86.1	103	1247	5.04	0.76	14.26
172	16.5		22.0	2.16	27	93.7	20	57	3.13	0.72	4.64
173	23		21.0	2.42	8	97.3	28	459	2.77	0.57	4.69
174	21		21.0	1.86	15	85.7	41	206	4.47	0.83	7.56
175	30		18.0	2.10	4	92.5	30	90	3.75	0.79	5.78
176	27		19.5	2.16	6	95.1	52	490	4.27	0.75	8.23
177	34		17.0	1.33	5	96.5	26	54	4.39	0.93	6.06
178	22		20.0	2.37	5	97.2	42	437	3.67	0.68	6.79
179	27		19.0	1.93	12	83.4	28	90	3.79	0.79	5.94
180	22.5		21.0	2.35	42	58.8	54	442	4.10	0.71	8.68
181	35.5		16.0	2.15	8	80.2	37	138	3.98	0.76	7.30

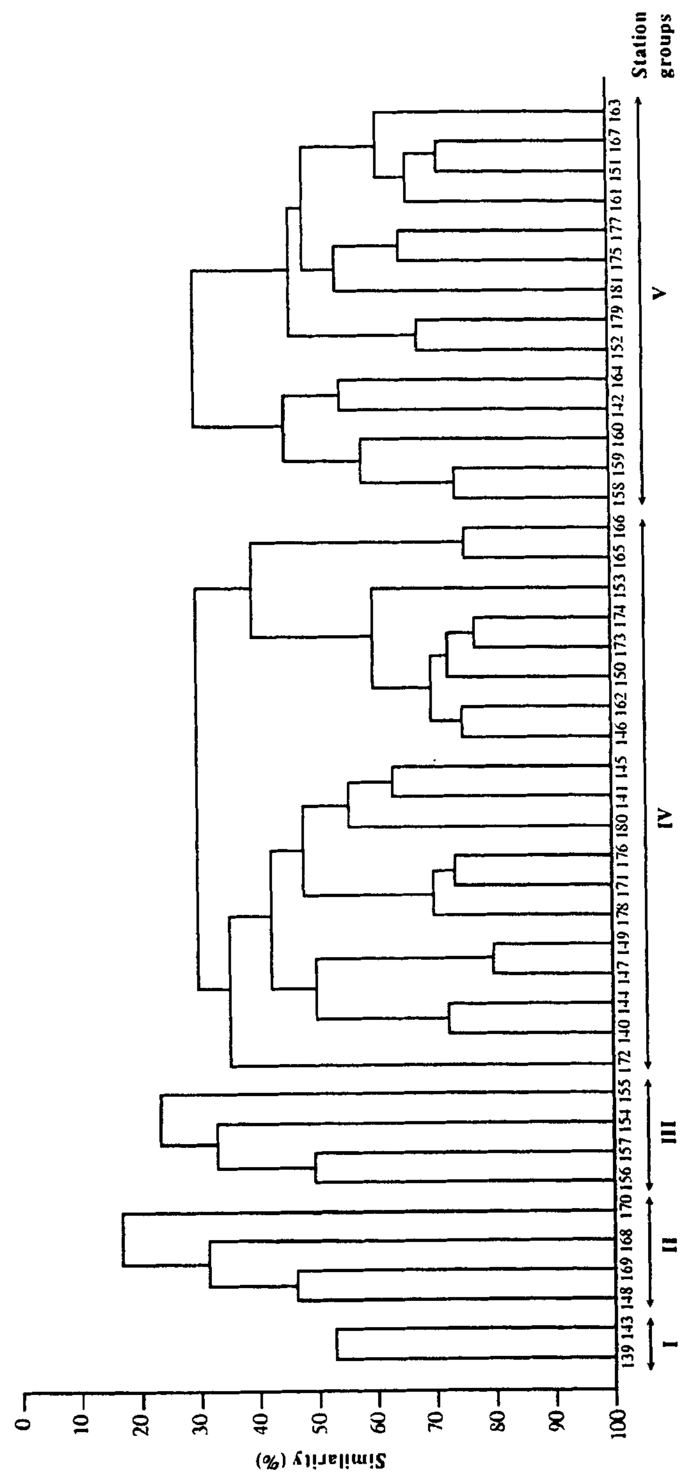

Figure 2. Faunal similarity between stations.

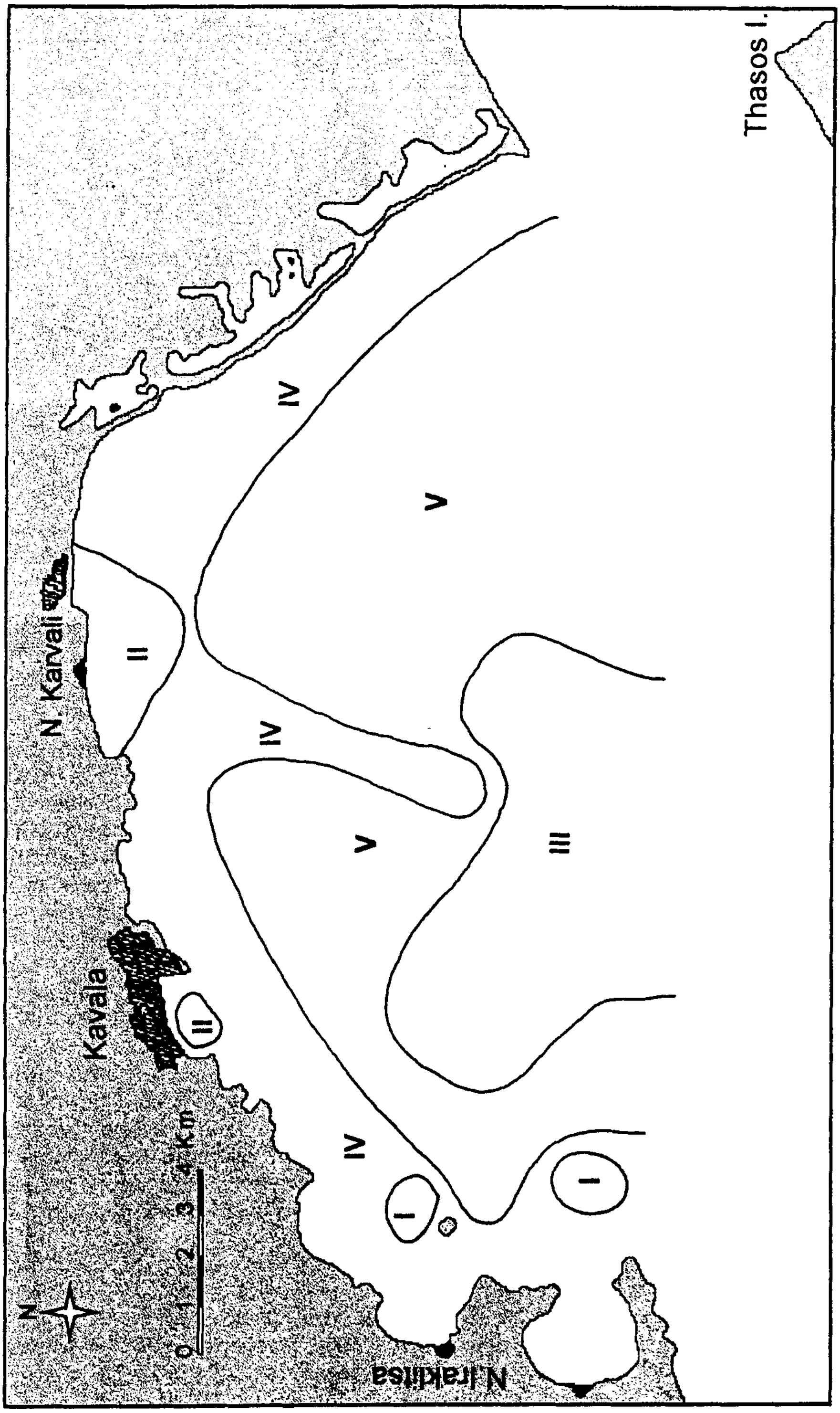

Figure 3. Distribution of the assemblages identified in Kavala Gulf.

Table 2. Benthic ecosystem parameters for Kavala Gulf station groups (mean ± S.E.).

	station group				
	I	II	III	IV	V
Nr. stations	2	4	4	19	14
Nr. species/ 0.2 m^2	47.0 ± 16.0	11.8 ± 3.3	13.0 ± 1.1	49.2 ± 4.6	22.6 ± 2.1
Nr. individuals/ 0.2 m^2	248.5 ± 35.5	81.0 ± 27.6	29.5 ± 4.6	722 ± 208.6	80.8 ± 9.9
H′	4.94 ± 0.30	2.17 ± 0.33	3.44 ± 0.11	3.61 ± 0.16	3.44 ± 0.20
J	0.91 ± 0.04	0.68 ± 0.11	0.93 ± 0.01	0.65 ± 0.02	0.79 ± 0.04
D	8.60 ± 3.22	2.50 ± 0.69	3.71 ± 0.16	7.74 ± 0.57	4.91 ± 0.38
Depth (m)	27.8 ± 2.3	11.4 ± 2.3	46 ± 1.5	23.5 ± 1.5	33.4 ± 1.2
Sediment temperature (°C)	19.5 ± 0.5	20.6 ± 0.4	16.1 ± 0.1	20.0 ± 0.4	17.2 ± 0.3
Sediment organic C (%)	0.69 ± 0.31	1.65 ± 0.31	2.28 ± 0.08	1.87 ± 0.16	2.01 ± 0.12
Grain size Md (μm)	982.0 ± 266.0	59.0 ± 17.1	7.0 ± 2.7	34.7 ± 6.7	9.1 ± 1.9
Sediment type	coarse to very coarse sand	silt to very fine sand	very fine to medium silt	very fine silt to very fine sand	very fine to medium silt
Description	coarse biogenic detritus	polluted area	deepest area	costal area	greatest area

Group IV includes 19 stations located on a strip running along almost the entire coast of the gulf, at depths from 16 to 29.5 m, with the exception of 2 stations (162, 153) located in the middle of the gulf, at depths of 36 and 38.5 m respectively (Fig. 1, 3). Sediment was very fine silt to very fine sand and the silt-clay fraction varied from 41.8 to 97.3%, with the exception of station 166 (Tables 1, 2). The corresponding assemblage is characterized by a high mean number of species and individuals, and the dominance of the sipunculan *Aspidosiphon muelleri* and the ophiuroid *Amphiura chiajei* (Table 3), being the top ranked species (Table 4). The large number of stations in this group permitted the correlation of total abundance, number of species and abundance of the dominant species with the Md and the organic carbon of the sediment. Only *A. muelleri* was significantly positively correlated with Md ($r = 0.485$, $df = 15$, $p < 0.05$) and *A. chiajei* with organic carbon ($r = 0.518$, $df = 18$, $p < 0.05$).

Group V accounting for 14 stations, covered the greatest part of the surveyed area, with a depth range of 25–39.5 m (Fig. 1, 3; Table 1). The substrate varied from very fine to medium silt and the silt-clay fraction from 67.1 to 97.6% (Tables 1, 2). The assemblage is characterized by the dominance of the sipunculan *A. muelleri*, the gastropod *Turritella communis* and the polychaete *Labioleanira yhleni* (Table 3), the latter being the second top ranked species (Table 4). In this station group, only *A. muelleri* was significantly positively correlated with Md ($r = 0.676$, $df = 12$, $p < 0.001$).

Table 4 rankes the top ten species of each station group (II–IV) according to their biological index value, and indicates their rank in the remaining station groups. As it can be seen in this table, group II (assemblage with *Loripes lacteus*) is characterized by the polychaete *Nephtys hombergii*, which had a mean dominance of 1.1% in group IV as well (Tables 3, 4), and the bivalve *L. lacteus*, Nemertea-1 and the polychaete *Owenia fusiformis*, which were not ranked in the remaining groups. From the total of the species ranked in the four assem-

Table 3. Mean dominances and mean abundances of the most dominant species in each of the 5 (I–V) station groups, given in bold numbers. If one of these species appears in other station groups, its corresponding values are also given in normal numbers.

	Mean dominance (%)					Mean (± SE) abundance				
Species	I	II	III	IV	V	I	II	III	IV	V
Paricardium roseum (Lamarck, 1819)	**12.1**	0.4	–	0.1	–	**30.0 ± 10.0**	0.3 ± 0.3	–	0.3 ± 0.2	–
Clausinella brongniartii (Payrandeau, 1826)	**7.4**	–	–	–	–	**18.5 ± 2.5**	–	–	–	–
Ampelisca sarsi Chevreux, 1888	**3.4**	–	–	0.1	–	**8.5 ± 7.5**	–	–	0.3 ± 0.2	–
Psammechinus microtuberculatus (Blainville, 1825)	**3.2**	–	–	–	–	**8.0 ± 8.0**	–	–	–	–
Aspidosiphon muelleri Diesing, 1851	2.0	**25.1**	1.0	**40.1**	**35.1**	5.0 ± 5.0	**20.3 ± 20.3**	0.3 ± 0.3	**289.7 ± 166.2**	**28.4 ± 7.5**
Loripes lacteus (Linnaeus, 1758)	–	**18.9**	–	0.1	–	–	**15.3 ± 13.3**	–	0.1 ± 0.1	–
Nephtys hombergii Savigny, 1818	–	**6.8**	–	1.1	–	–	**5.5 ± 1.0**	–	8.2 ± 3.1	–
Tellina nitida Poli, 1791	–	**17.7**	1.0	0.1	0.4	–	**14.3 ± 13.9**	0.3 ± 0.3	0.4 ± 0.2	0.3 ± 0.2
Terebellides stroemi M. Sars, 1835	0.8	–	**11.9**	2.2	2.4	2.0 ± 2.0	–	**3.5 ± 1.0**	15.7 ± 6.3	1.9 ± 0.3
Sternaspis scutata (Renier, 1807)	–	–	**10.2**	0.6	1.7	–	–	**3.0 ± 1.1**	4.6 ± 1.2	1.4 ± 0.4
Lumbrineris latreilli (Audouin & Milne Edwards, 1834)	2.2	–	**8.5**	1.8	3.3	5.5 ± 2.5	–	**2.5 ± 1.5**	12.7 ± 6.7	2.7 ± 0.8
Chaetozone setosa Malmgren, 1867	–	0.4	**8.5**	0.2	1.1	–	0.3 ± 0.3	**2.5 ± 1.3**	1.6 ± 0.6	0.9 ± 0.4
Labioleanira yhleni (Malmgren, 1867)	–	0.6	**7.8**	1.5	**5.8**	–	0.5 ± 0.3	**2.3 ± 0.5**	10.8 ± 2.3	**4.7 ± 1.1**
Turritella communis Risso, 1826	–	–	3.4	3.6	**7.8**	–	–	1.0 ± 1.0	25.9 ± 9.5	**6.3 ± 2.1**
Amphiura chiajei Forbes, 1843	3.0	–	1.0	**8.7**	3.6	7.5 ± 0.5	–	0.3 ± 0.3	**62.8 ± 23.5**	2.9 ± 1.2

Table 4. Top ten ranked species per station group (Bold numbers), according to their biological index value, with their rank in the other station groups.

Species	station group			
	III	V	IV	II
Terebellides stroemi M. SARS 1835	**1**	9	7	–
Sthenolepis yhleni (MALMGREN, 1867)	**2**	**2**	**5**	11
Sternaspis scutata (RENIER, 1807)	**3**	14	14	–
Chaetozone setosa MALMGREN, 1867	**4**	12	28	19
Lumbrineris latreilli (AUDOUIN & MILNE EDWARDS, 1834)	**5**	**4**	13	–
Corbula gibba (OLIVI, 1792)	**6**	13	**10**	17
Nucula sulcata BRONN, 1831	**7**	11	**8**	–
Cirratulus cirratus (O. F. MÜLLER, 1776)	**8**	**10**	–	–
Turritella communis RISSO, 1826	**9**	**3**	**3**	–
Abra alba (WOOD, 1802)	**10**	34	–	**9**
Aspidosiphon muelleri DIESING, 1851	–	**1**	**1**	**6**
Melinna palmata GRUBE, 1870	–	**5**	**9**	–
Amphiura chiajei FORBES, 1843	–	**6**	**2**	–
Amphiura filiformis (O. F. MÜLLER, 1776)	19	**7**	12	–
Labidoplax digitata (MONTAGU, 1815)	–	**8**	20	–
Maldane glebifex GRUBE, 1860	–	16	**4**	–
Nepthys hystricis MCINTOSH, 1900	16	–	**6**	**10**
Nephthys hombergii SAVIGNY, 1818	–	–	15	**1**
Loripes lacteus (LINNAEUS, 1758)	–	–	–	**2**
Nemertea-1	–	–	–	**3**
Tellina nitida POLL, 1791	17	33	–	**4**
Glycera unicornis SAVIGNY, 1818	20	24	25	**5**
Owenia fusiformis DELLE CHIAJE, 1842	–	–	–	**7**
Processa nouveli AL-ADHUB & WILLIAMSON, 1975	–	–	23	**8**
Total number of ranked species:	14	18	18	13

blages, the smallest number of species (13) was ranked in the assemblage of group II (Table 4). In group III (assemblage of *Sternaspis scutata*), which was settled in the greatest depths of the gulf, characteristic species were the polychaetes *Terebellides stroemi*, *Labioleanira yhleni* and *Sternaspis scutata* (Table 4); the last species is ranked in lower positions in the other assemblages. Group IV (assemblage of *Amphiura chiajei*) is characterized by the sipunculan *Aspidosiphon muelleri*, the ophiuroid *Amphiura chiajei*, the gastropod *Turritella communis* and the polychaete *Maldane glebifex*, but only *A. chiajei* and *M. glebifex* are ranked in lower position in the other assemblages. Group V (assemblage of *Amphiura filiformis*) is characterized by the ophiuroid *A. filiformis* and the holothurioid *Labidoplax digitata*, since the top ranked species in this assemblage are also top ranked in other groups.

Comparisons between two and all station groups, concerning benthic ecosystem parameters are presented in Table 5. The compared parameters were significantly different among all groups of stations and in most cases between couples of station groups.

Ordination of stations and species based on the detrended correspondence analysis (Fig. 4) produced three axes having Eigen values of 0.668, 0.439 and 0.250 respectively. Axis I seems to reflect pollution, since the three stations and the species included in the groups with high values belong to polluted areas. Axis II seems to reflect the particle size composition of the substrate. The two stations with the highest Md values belonging to a distinguished assemblage of the gulf, have much higher values on axis II; furthermore, the most of the

Table 5. Comparison between two and five station groups (Fisher LSD coefficient and factor F, respectively) concerning benthic ecosystem parameters.

Station groups	NS/0.2 m^2	NI/0.2 m^2	H′	J	D	Depth	Sed. temp.	Sed. Org. C	Md
I–II	0.763*	1.368	0.374*	0.340	0.598*	0.415*	0.138	0.896*	1.290*
I–III	0.763*	1.368*	0.374	0.340	0.598*	0.415*	0.138*	0.896*	1.290*
I–IV	0.655	1.174	0.321*	0.292*	0.514	0.357	0.118	0.769*	1.107*
I–V	0.666*	1.194*	0.326*	0.297	0.522*	0.363	0.120*	0.782*	1.126*
II–III	0.623	1.117	0.305*	0.278*	0.489*	0.339*	0.113*	0.732	1.053*
II–IV	0.485*	0.869*	0.237*	0.216	0.380*	0.264*	0.088	0.569	0.819
II–V	0.500*	0.898	0.245*	0.223	0.392*	0.272*	0.090*	0.587	0.845*
III–IV	0.485*	0.869*	0.237	0.216*	0.380*	0.264*	0.088*	0.569	0.819*
III–V	0.500	0.896	0.245	0.223	0.392	0.272*	0.090	0.587	0.845
IV–V	0.310*	0.556*	0.152	0.138*	0.243*	0.169*	0.056*	0.365	0.525*
I, II, III, IV, V	16.839***	19.652***	6.765***	4.674**	13.604***	25.205***	12.262***	2.629*	25.175***

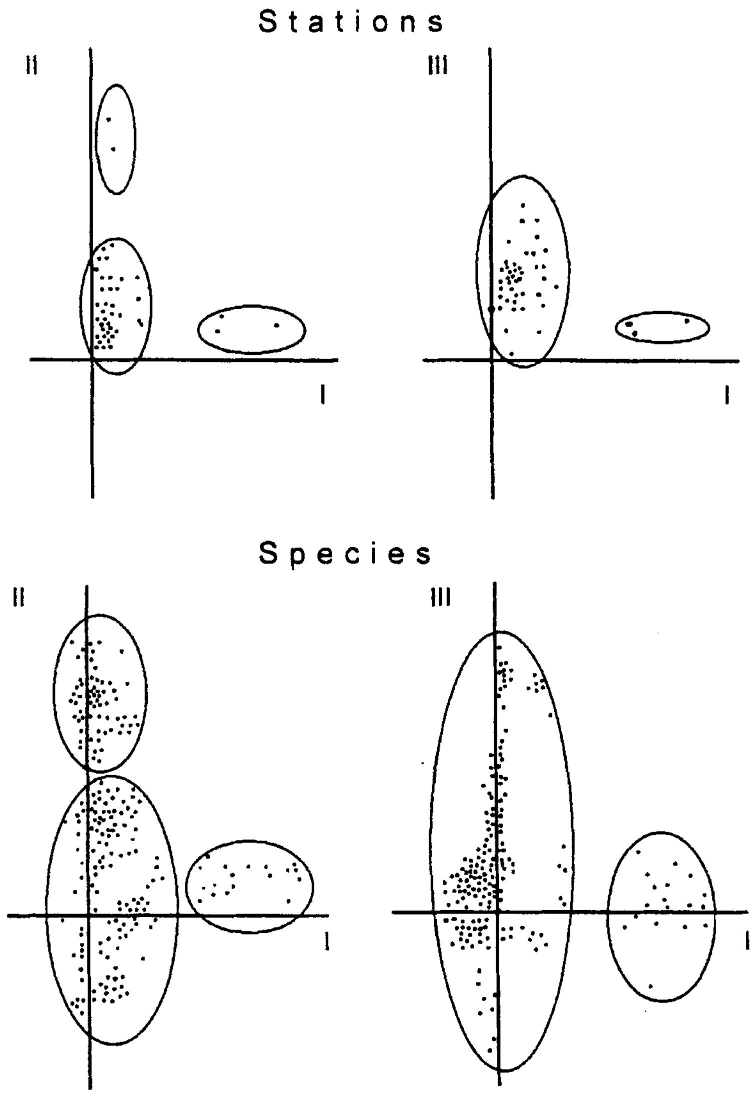

Figure 4. Samples (stations) and species distribution according to the correspondences analysis method.

species of these two stations, together with certain species from other stations (the most euryoecious) constitute a separate group. Axis III possibly reflects the combined action of the depth and organic carbon of the sediment on the fauna.

4. Discussion

The classification of the infralittoral and circalittoral zones of Kavala Gulf revealed five recognizable assemblages: (1) a gravelly sand assemblage with *Parvicardium roseum* and

Clausinella brongniartii (Group I); (2) a sandy-silt assemblage in the polluted area, with *Loripes lacteus* and *Nephtys hombergii* (Group II); (3) a clayey silt assemblage with *Terebellides stroemi* and *Sternaspis scutata* (Group III); (4) a sandy silt assemblage with *Amphiura chiajei* (Group IV); and (5) a silt assemblage with *Labioleanira yhleni* (Group V).

PÉRÈS and PICARD (1964) and PÉRÈS (1967a, 1982) described the assemblage of the "upper mudy-sand in sheltered areas" which seems to correspond to the sandy silt assemblage with *Loripes lacteus* found in the polluted area of Kavala Gulf; these authors included the bivalve *L. lacteus* in the characteristic species of this assemblage. In Kavala Gulf, the bivalve *L. lacteus* was found in high abundance only in the station located in the port of Kavala. At the other, less sheltered stations of the same assemblage, its abundance was low. However, only a few species of the other groups reported by the above authors were present in Kavala assemblage. The areas in Kavala Gulf, where the three stations of this assemblage are located, receives domestic sewage or industrial effluents (KOUKOURAS *et al.*, 1982). This could possibly be the reason for the observed low diversity in the sandy-silt assemblage with *Loripes lacteus* and *Nephtys hombergii* and consequently the absence of most of the species reported by PÉRÈS and PICARD (1964) and PÉRÈS (1967a, 1982) for the assemblage of "upper mudy-sand in sheltered areas"; moreover, among the species of the assemblage of Kavala are included the bivalve *Parvicardium exiguum*, considered as a pollution indicator (PICARD, 1965) the polychaetes *Glycera unicornis, Nepthys hombergii* and certain polychaetes of the family Capitellidae, considered as common inhabitants of polluted areas (PICARD, 1965; BELLAN-SANTINI, 1968; COGNETTI, 1970).

ELEFTHERIOU *et al.* (1986) have described a similar assemblage from the polluted area of Irvine Bay on the coasts of Scotland. However, out of the 20 species listed by them, only two polychaetes have been found in Kavala assemblage. These are the cosmopolitan species *Nephtys hombergii* and *Chaetozone setosa* which are among the most dominant in both assemblages. The remaining species of Kavala asssemblage seem to be replaced in the Irvine Bay assemblage by different species of the same genus in most of the cases. This should be attributed to the fact the two areas are zoogeographically quite different.

The gravelly sand assemblage with *Parvicardium roseum* and *Clausinella brongniartii* found in Kavala Gulf, should be considered as a separate facies of the broader "assemblage of the coastal biogenic detritus" originally described by PÉRÈS and PICARD (1964), PICARD (1965), PÉRÈS (1967, 1982). In both cases, the sediment consists of coarse biogenic detritus with an admixture of sand. The restricted number of stations corresponding to this assemblage in Kavala Gulf is the reason for the few species in common with the assemblage described by the above authors. Among the co-occurring species are the echinoids *Psammechinus microtuberculatus* and *Echinocyamus pusillus* (O. F. MÜLLER, 1776), the ophiuroids *Ophiura albida* (FORBES, 1839) and *O. grubei* HELLER, 1863, the bivalves *Psammobia fervensis* (GMELIN, 1791) and *Abra prismatica* (MONTAGU, 1808), and the decapods *Parthenope massena* (ROUX, 1830) and *Paguristes eremita* (LINNAEUS, 1767). The most dominant bivalve in the Kavala assemblage is *Clausinella brongniartii* which, according to PÉRÈS and PICARD (1964), usually occurs in the "assemblage of the self-edge detritus"; the latter has a lot of elements in common with the former. *C. brogniartii*, in the adjacent area of Strymonikos Gulf was characterized as an accessory species of the assemblage of the transitional zone with *Nephtys hombergii* settled in similar depths: 10–30 m (DOUNAS, 1986; DOUNAS and KOUKOURAS, 1992).

The review of the relevant literature did not reveal any description of a similar assemblage in the North Atlantic; not even an assemblage similar to the broader "assemblage of the coastal detritus" described by PÉRÈS and PICARD (1964) and PÉRÈS (1967a, b, 1982). This may be due to the pecularities of the Mediterranean, and moreover to the fact that the assemblages established on soft bottoms are unstable and show a less stable organization. ROS *et al.* (1985) attribute this to the reduced species richness and the increased communities diversification, and moreover to the fact that the large number of different communities from soft bottoms results from the more fluctuating nature of the substrates which produces communities almost as variable as the planktonic ones.

The other three assemblages described in Kavala Gulf, as it results from their faunal composition, undoubtedly belong to THORSON's (1957) "North-Mediterranean community of *Amphiura filiformis-Amphiura chiajei*", or the community of silty bottoms with *Amphiura filiformis* reported by GUILLE (1970) and DESBRUYÉRES *et al.* (1973) from the French and Spanish Catalan coasts respectively. The above broad community, mainly due to local differentiations of the sediment composition, can appear as different sub-communities or facies, or even transitional zones (e.g. BUCHANAN, 1963; PÉRÈS and PICARD, 1964; GLEMAREC, 1969; KEEGAN *et al.*, 1976; PÉRÈS, 1982; DOUNAS and KOUKOURAS, 1992) reflecting qualitative and quantitative differences in the composition of species and individuals of this community. For each of these three assemblages found in Kavala Gulf, we can make the following comments:

The silt assemblage with *Labioleanira yhleni* (= *Sthenolepis yhleni*), as it is obvious from the review of the literature, is described for the first time; nevertheless, it should be considered as a local variation of the *A. filiformis-A. chiajei* community and especially of the sub-community with *A. filiformis* (BUCHANAN, 1963; KEEGAN *et al.*, 1976). The more closely related assemblages to the silt assemblage with *L. yhleni* seems to be the station group IV mentioned by KARAKASIS and ELEFTHERIOU (1997) from the continental shelf of Crete and the *Melinna* Association described by KEEGAN *et al.* (1976) from the Galway Bay, on the West coast of Ireland. Among the co-occurring species in these three assemblages, the polychaete *Melina palmata* is included, being a characteristic species in the assemblage of Galway Bay.

The clayey silt assemblage with *Terebellides stroemi* and *Sternaspis scutata* seems to be very similar with the sub-community of silt with *Nucula sulcata* described by GUILLE (1970) from the Mediterranean coast of France, with the difference that in the latter, *T. stroemi* is second after *N. sulcata* concerning its biological index value and mean dominance. This assemblage is also similar to the sandy silt assemblage with *Sternaspis scutata* described in the adjacent Strymonikos Gulf (DOUNAS and KOUKOURAS, 1992). In the NE Atlantic, the most relative assemblage seems to be the "Typical" Association of *A. filiformis* sub-community described by KEEGAN *et al.* (1976) in Galway Bay. Among the dominant species of the two assemblages, however, only 10 are co-occurring, including the ophiuroid *A. filiformis* and the holothuroid *Labidoplax digitata*.

Finally, the sandy-silt assemblage with *Amphiura chiajei* seems to be homologous with the sub-community of silt biogenic detritus with *Timoclea ovata* described by GUILLE (1970) from the French Mediterranean coast and by DESBRUYÉRES *et al.* (1973) from the Spanish Mediterranean coast, with the gravelly sand assemblage with *T. ovata* described in Strymonikos Gulf (DOUNAS and KOUKOURAS, 1992), but also with the *Amphiura chiajei* sub-community of the NE Atlantic, described from off the coast of Northumberland (BUCHANAN, 1963) and the Galway Bay (KEEGAN *et al.*, 1976); in the last two assemblages, however, the species *A. chiajei* is absent.

ZARKANELLAS and KATTOULAS (1982) studied the benthic assemblages of soft substrate in the neighbouring area of upper Thermaikos Gulf; their faunal data show that many of the species dominating in Kavala Gulf, appear to be dominant in various sites of this area. However, comparisons cannot be made, since the treatment of the data by the above authors does not permit the identification of the existing assemblages.

Summarizing, we can note that the results of the research on the benthic assemblages in Kavala Gulf support the opinion of DOUNAS and KOUKOURAS (1992) that the benthic assemblages of the North Aegean show important similarities with the corresponding well-studied assemblages of the western basin of the Mediterranean, as suggested by French marine biologists (e.g., PÉRÈS, 1967). Furthermore, the corresponding assemblages in the NE Atlantic and the Mediterranean seem to have profound differences in their composition.

5. Summary

For the description of soft bottom assemblages in Kavala Gulf (North Aegean Sea), 43 sampling stations were selected. The classification method used revealed the presence of five faunal assemblages: i) a gravelly sand assemblage with *Parvicardium roseum* and *Clausinella brongniartii*, which should be considered as a separate facies of the broad "assemblage of coastal biogenic detritus"; ii) a sandy silt assemblage with *Loripes lacteus* and *Nephtys hombergii*, found in areas subjected to the influence of domestic sewage or industrial effluents; iii) a clayey silt assemblage with *Terebellides stroemi* and *Sternaspis scutata*; iv) a sandy silt assemblage with *Amphiura chiajei* and v) a silt assemblage with *Labioleanira yhleni*. The last three assemblages belong to a single community, that of silty sediments with *Amphiura filiformis*. Local differentiations of the environmental conditions (depth, substrate) within this community resulted in three different assemblages (sub-communities). Of these, the silt assemblage with *Labioleanira yhleni* is reported for the first time. The comparison of the identified assemblages with other corresponding ones from the Aegean, the Western Mediterranean and the NE Atlantic shows that there is an increasing differentiation from the Aegean towards the NE Atlantic.

6. References

Bellan-Santini, D., 1968: Influence de la pollution sur les peuplements benthiques. – Rev. Int. Océanogr. Med. **10**: 27–53.

Bogdanos, C. and J. Satsmadjis, 1983: The macrozoobenthos of an Aegean embayment. – Thalassographica **6**: 77–105.

Buchanan, J. B., 1963: The Bottom Fauna Communities and their Sediment Relationships off the coast of Northumberland. – Oikos **14**: 154–175.

Buchanan, J. B., 1984: Sediment analysis. pp. 41–65. – *In*: N. A. Holme and A. D. McIntyre (eds.). Methods for the study of Marine Benthos. – I.B.P. Handbook No. **16**, Oxford.

Cognetti, G., 1970: Influenza degli inquinamenti sulli popolezioni del benthos marino. – Pubbl. Staz. Zool. Napoli **38** Suppl.: 1–16.

Desbruyéres, D., A. Guille and J. Ramos, 1973: Bionomie benthique du plateau continental de la côte Catalane Espagnole. – Vie et Milieu **23** (2B): 335–363.

Diapoulis, A. and C. Bogdanos, 1983: Preliminary study of soft substrate macrozoobenthos and marine flora in the bay of Gera (Lesvos Island, Greece). – Thalassographica **6**: 127–139.

Dounas, C., 1986: Study of the benthic macrofaunal assemblages of the soft substratum in Strymonikos Gulf (in Greek). – PhD thesis, Sci. Annals Fac. Phys. & Mathem., Univ. Thessaloniki **23** (Suppl. 55): 1–185.

Dounas, C. and A. Koukouras, 1992: Circalittoral macrobenthic asssemblages of Strymonikos Gulf (North Aegean Sea). – P.S.Z.N.I.: Marine Ecology **13**: 85–99.

Ekman, S., 1953: Zoogeography of the sea. – Sidgwick & Jackson, London.

Eleftheriou, A., M. R. Robertson and D. J. Murison, 1986: The benthic fauna of sandy bays, with particular reference to Irvine Bay. – Proc. Royal Soc. Edinb. **90B**: 317–327.

Galil, B. and C. Lewinsohn, 1981: Macrobenthic communities of the eastern Mediterranean continental shelf. – P.S.Z.N.I.: Marine Ecology **2**: 343–352.

Geldiay, R. and A. Kocatas, 1972: Note préliminaire sur les peuplements benthiques du golfe d'Izmir (in Turkish). Sci. Monogr. – Fac. Sci., Ege Univ. **12**: 1–34.

Gilat, E., 1964: The macrobenthic invertebrate communities on the Mediterranean continental shelf of Israel. – Bull. Inst. Océanogr., Monaco **62** (1290): 1–46.

Glémarec, M., 1969: Les peuplements benthiques du plateau continental nord-Gascogne. – Thèse, Univ. Paris, 167 pp.

Gouvis, N. and A. Koukouras, 1993: Macrozoobenthic assemblages of the Evros Delta (North Aegean Sea). – Int. Revue ges. Hydrobiol. **78**: 59–82.

Guille, A., 1970: Bionomie bénthique du plateau continental de la côte catalane Française. II. Les communautés de la macrofauna. – Vie et Milieu **21**: 149–280.

HILL, M. O., 1979: Decorana. A Fortran programme for Detrended Correspondence Analysis and Reciprocal Averaging. – Cornell Univ. Ithaca, New York, 30 pp.

KARAKASSIS, I., 1991: Contribution to the study of the benthic ecosystem of the continental shelf of Crete. – PhD thesis, University of Crete, Heraklion.

KARAKASSIS, I. and A. ELEFTHERIOU, 1997: The continental shelf of Crete: structure of macrobenthic communities. – Mar. Ecol. Prog. Ser. **160**: 185–196.

KATTOULAS, M., A. KOUKOURAS and E. VOULTSIADOU, 1980: Preliminary results on the impact of pollution on the benthic ecosystems in some littoral areas of the North Aegean Sea. – Special Edition of the Ministry of Coordination: 10–14 (in Greek).

KEEGAN, B. F., B. O'CONNOR, D. MCGRATH and G. KÖNNECKER, 1976: The *Amphiura filiformis – Amphiura chiajei* community in Galway Bay (west coast of Ireland) – a preliminary account. – Thalassia Jugosl. **12**: 189–198.

KISSELEVA, M., 1961: Répartition qualitative et quantitative du benthos dans la région de Dardanelles en mer Egée (in Russian). – Tr. Sevastop. Biol. Stn. **14**: 135–146.

KISSELEVA, M., 1963: La distribution du benthos qualitative et quantitative dans la mer Egée (in Russian). – Tr. Sevastop. Biol. Stn. **16**: 192–200.

KISSELEVA, M., 1983: Comparative characteristics of the benthos at some banks in the Aegean Sea. – Thalassographica **6**: 107–118.

KISSELEVA, M. and V. D. TCHUKHTCHIN, 1965: Certain data on the quantitative development of the Macro- and Meri-benthos in the Eastern part of the Mediterranean Sea. – A. K. Nank, C.C.C.P. Okean. K.: 192 pp.

KOUKOURAS, A., M. KATTOULAS, H. CHINTIROGLOU and N. GOUVIS, 1982a: Benthic bionomy of the North Aegean Sea: XI. Estimation on the pollution in the Gulf of Thessaloniki, on the basis of the composition of the benthic fauna. – Proceedings of the 3rd Ecological Meeting of the Greek Ecological Society, Athens: 17–23 (in Greek).

KOUKOURAS, A., M. KATTOULAS, C. DOUNAS, TH. KEVREKIDIS and A. GOGOU, 1982b: Benthic bionomy of the North Aegean Sea. XV. Seasonal changes in the benthic fauna of the Gulf of Kavala. – Proceedings of the 4th Symposium of the Greek Biological Society, Thessaloniki: 91–93 (in Greek).

KOUKOURAS, A. and A. RUSSO, 1991: Midlittoral soft substratum macrofaunal assemblages in the North Aegean Sea. – P.S.Z.N.I.: Marine Ecology **12**: 293–316.

KOUKOURAS, A., E. VOULTSIADOU-KOUKOURA, TH. KEVREKIDIS and D. VAFIDIS, 1995: Ascidian fauna of the Aegean Sea with a check list of the eastern Mediterranean and Black Sea species. – Ann. Inst. océanogr., Paris **71**: 19–34.

LANCE, G. N. and W. T. WILLIAMS, 1967: A general theory of classificatory sorting strategies. I. Hierarchical systems. – Comput. J.: 373–380.

MAKKAVIEVA, E. B., 1963: Quelques peuplements des zones sableuses de la mer Egée (in Russian). – Tr. Sevastop. Biol. Stn. **16**: 211–214.

MARGALEF, R., 1957: La teoria de information en ecologia. – Mem. Real. Acad. Cienc. Artes Barcelona **32**: 373–449. Translation: Information theory in ecology. – Gen. Syst. **3**: 36–71 (1958).

PÉRÈS, J. M., 1967a: Les biocenoses benthiques dans le système phytal. – Recl. Trav. Stn. Mar. Endoume **42**: 1–113.

PÉRÈS, J. M., 1967b: The Mediterranean benthos. – Oceanogr. Mar. Biol. Ann. Rev. **5**: 449–533.

PÉRÈS, J. M., 1982: Zonations and Organismic Assemblages. Chapter 6. Major benthic assemblages. pp. 373–522. – *In*: O. KINNE (ed.). – Marine Ecology, Ocean Management, Wiley Chichester **5** (1): 373–522.

PÉRÈS, J. M. and J. PICARD, 1958: Recherches sur les peuplements benthiques de la Méditerranée nord-orientale. – Ann. Inst. Océanogr. Monaco **34**: 213–291.

PÉRÈS, J. M. and J. PICARD, 1964: Nouveau manuel de bionomie benthique de la mer Mediterranée. – Recl. Trav. Stn. Mar. Endoume **31**: 1–137.

PICARD, J., 1965: Recherches qualitatives sur les biocenoses marines des substrates meubles dragables de la région Marseillaise. – Recl. Trav. Stn. Mar. Endoume **52**: 1–160.

PIELOU, G. C., 1969: An introduction to mathematical Ecology. – Ed. John Wiley & Sons, New York: 286 pp.

POR, F. D. and C. DIMENTMAN, 1989: The Legacy of Tethys. An Aquatic Biogeography of the Levant. – *In*: DUMONT, H. J. & WERGEL, M. J. A. (Eds). Monographiae Biologicae **63**: 214 p. Dordrecht, Kluwer Academic Publishers.

ROS, J. D., J. ROMERO, E. BALLESTEROS and J. M. GILI, 1985: 8. Diving in blue water. The benthos: 233–295. – *In*: MARGALEF, R. (Ed.). Key environments: Western Mediterranean. Pergamon Press.

SANDERS, H. L., 1968: Marine benthic diversity: A comparative study. – The American Naturalist **102**: 243–282.

SANTOS, S. L. and S. A. BLOOM, 1983: Evaluation of succession in an estuarine macrobenthic soft-bottom community near Tampa, Florida. – Int. Revue ges. Hydrobiol. **68**: 617–632.

TCHUKHTCHIN, V. D., 1963: Répartition quantitative et qualitative du benthos dans la Méditerranée orientale (in Russian). – Tr. Sevastop. Biol. Stn. **16**: 215–223.

THORSON, G., 1957: Bottom communities. – Geol. Soc. America **1**: 461–534.

VAMVAKAS, C., 1970: Peuplements benthiques des substrats meubles du sud de la mer Egée. – Téthys **2**: 89–129.

VAMVAKAS, C., 1971: Contribution to the study of soft substratum benthic biocenoses of Greek seas. – Hellenic Oceanol. Limnol. **10**: 1–152.

VOULTSIADOU-KOUKOURA, H., A. KOUKOURAS and A. ELEFTHERIOU, 1987: Macrofauna associated with the sponge *Verongia aerophoba* in the North Aegean Sea. – Estuar. Coast. shelf S. **24**: 265–278.

ZARKANELLAS, A. J., 1977: Benthic studies in Kavala Gulf, Greece. – Thalassographica **1**: 266–278.

ZARKANELLAS, A. J. and M. KATTOULAS, 1982: The ecology of benthos in the gulf of Thermaikos, Greece. I. Environmental conditions and benthic biotic indices. – P.S.Z.N.I.: Marine Ecology **3**: 21–39.

Manuscript received November 26th, 1997; revised August 14th, 1998; accepted August 26th, 1998