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Original article

Structure of the artificial hard substrate assemblages in ports in Thermaikos Gulf (North Aegean Sea)

Assemblages de substrats durs artificiels dans des ports du nord de la mer Égée (golfe de Thermaikos)

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Abstract

The present study describes the hard substrate assemblages established on the concrete blocks of three ports placed in gradually longer distances from the main source of pollution in Thermaikos Gulf. The samplings were performed on a seasonal basis for a 2-year period. The data analysis indicates a clear separation of the assemblages from each port. Evenness and Shannon–Weaver diversity indices were calculated and their values were found to be quite high. This fact, combined with the seasonal pattern that these assemblages hold, reveals stability and a good adaptation of their faunistic components to local environmental conditions. A change due to the construction of a new block functioning as a surge barrier was detectable at the station of N. Michaniona. Once again, biomonitoring proves to be essential in order to obtain useful information about the water conditions. Emphasis was laid on the taxa of Polychaeta by analyzing their numerical abundance and their feeding guilds separately. The results were very similar, a fact that supports the opinion that a specific taxonomic group can be used for the description and the monitoring in many different cases.

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Résumé

Ce travail décrit les assemblages de substrats durs qui se sont établis sur des blocs dans trois ports de plus en plus éloignés des sources de pollution dans le golfe de Thermaikos. Des prélèvements saisonniers durant deux années montrent une séparation nette des assemblages des trois ports. Les indices de diversité (Shannon–Weaver) et d'équitabilité sont plutôt élevés. Ce fait, ainsi que le schéma saisonnier, révèlent une stabilité et une bonne adaptation de la faune à son environnement. Un changement dû à la construction d'un nouveau bloc établi pour barrer la houle est détectable à la station du port N Michaniona. Une fois de plus, le suivi biologique paraît essentiel pour obtenir des informations utiles sur les conditions environnementales. L'accent est mis sur les taxons de polychètes en mesurant l'abondance des différentes guildes trophiques. Les résultats sont voisins, ce qui prouverait qu'un groupe taxinomique spécifique peut être utilisé pour décrire et suivre l'évolution dans pas mal de cas.

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Keywords: Hard substrate; Ports; Pollution; Polychaeta; Trophic relations

Mots clés : Substrats durs ; Ports ; Pollution ; Polychètes ; Relations trophiques

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1. Introduction

The research for the assessment of sea pollution has troubled the scientific society worldwide. It is generally true that when the numerical abundance is high, diversity is low. According to Bellan-Santini et al. (1994), this is more obvious for oligotrophic systems like the Mediterranean Sea, where in normal conditions we observe low abundance and high diversity. It is also acceptable that when an assemblage shows variations of its normal faunal composition or loses its seasonal pattern, a kind of disturbance in the area has probably occurred (Gray and Mirza, 1979).

Studies on marine benthic ecology have proved to be extremely useful tools, since they provide data applicable for biomonitoring. During the last 60 years, numerous research programs were dedicated to the collection of data concerning the Mediterranean benthic assemblages, as the existing bibliographic references prove. This attempt mostly concerns the soft substrate assemblages, mainly due to the easiest application of soft substrate sampling techniques. The majority of the existing data on hard substrate assemblages derives from studies in Marseille and Italy (Pérès and Picard, 1964; Bellan-Santini, 1968, 1981; Bellan-Santini et al., 1976, 1994; Tack Kit, 1976; Bellan, 1980; Bitar, 1982; Desrosiers et al., 1986 and others). Furthermore, information relating to both structure and function of the artificial hard substrate assemblages in ports is very limited (Hargrave and Thiel, 1983; Bellan and Pérès, 1994; Baxevanis and Chintiroglou, 2000).

Many authors point out that the structure of benthic assemblages reflects the integrated conditions over a period of time. Consequently this kind of data is extremely helpful for pollution impact studies due to anthropogenic interference. In order to be able to identify such cases, as forced by many international directives and conventions, it is necessary to create a database concerning the composition of natural assemblages (Gaston and Spicer, 1996).

The aim of this study is to give for the first time the results on the structure and organization (terms as given from Desrosiers et al., 1986) of hard substrate assemblages in three ports (with mainly different operation) of Thermaikos Gulf (North Aegean Sea), in order to (a) register the benthic invertebrate fauna in space and time, (b) evaluate the effect of pollution on the structure of these assemblages and (c) assess the environmental impact of technical port constructions in the wider geographical area.

2. Materials and methods

2.1. Description of sampling stations

The choice of sampling stations was based on three criteria: (1) their distance from the main source of pollution which is located at the northwest side of the gulf, (2) their homogeneity in terms of substrate and time of construction (concrete blocks, more than 15 years in order to obtain assemblages in a late stage of the colonization process), and (3) their differences concerning the degree and kind of pollution.

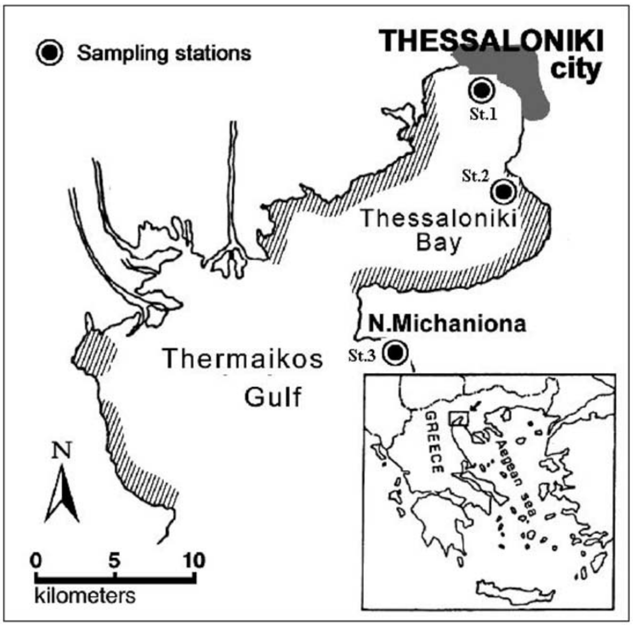

Fig. 1. Map of the three sampling stations where St.1 shows the main port of Thessaloniki, St.2, the marina of Kalamaria and St.3, the fishery port in N. Mihaniona.

2.2. Station 1: main port of Thessaloniki

The main port of Thessaloniki is located at the northwestern side of the bay (Fig. 1), thus the closest to the main pollution sources. It is the second biggest port in Greece and harbors a great number of commercial and passenger boats every day. It is under the influence of sewage produced by the neighboring industrial area of Thessaloniki, but it also receives the majority of city's urban sewage. The mean depth reaches 10 m and is strongly exposed to southern winds, resulting in a satisfactory water renewal.

2.3. Station 2: marina of Kalamaria

The marina of Kalamaria is located at the northeastern side of the city (Fig. 1). Its relatively small size restricts its function to harboring only a small number of littoral fishing boats and yachts anchors there. The marina receives urban sewage from the area of Kalamaria and it is additionally affected by toxic materials coming from the painting of tourist yachts. Two important factors in this site are the small depth (mean depth at about 2 m, maximum at 4 m) and protection from the wave action due to a storm-surge barrier in parallel with the shore, creating an artificial wall and, thus, obstructing water renewal.

2.4. Station 3: port of N. Michaniona

This station is located at the northeastern side of Thermaikos Gulf, 30 km away from the city of Thessaloniki (Fig. 1).

Consequently it is far away from industrial and the majority of urban sewage, receiving only local rejects. It serves mainly the fisheries, containing a great number and variety of boats. Almost the entire fishing fleet of Thermaikos Gulf anchors there. Besides the fishery boats waste, this station receives organic material from the estuaries system of Axios Loudias and Aliakmonas rivers located at the northwestern side of the gulf. We must also add the fact that the port is strongly exposed to the north winds. So, in combination with its depth (mean depth around 6 m), we can suggest that water renewal is satisfactory.

2.5. Physico-chemical factors

During this study, the main abiotic factors (pH, temperature, salinity, conductivity, dissolved oxygen, total hydrodynamism and water clarity) were measured at each sampling site on a monthly basis. All measurements were made with a WTW salinity-conductivity-O_2 meter and Lovibond Checkit (pH-meter) micro-electronic equipment. The water clarity was determined using the Secchi disc. The evaluation of total hydro-dynamism was based on the corrosion of plaster into the water (Kaandorp, 1986).

2.6. Classification of the Polychaetes' feeding guilds

Overall 57 species of Polychaetes were identified in our samples and classified in 10 feeding guilds, based on the models proposed by Fauchald and Jumars (1979). These guilds were: BMJ, BMX, BSX, CMJ, CDJ, HMJ, SMT, SDT, SST, FST, where B stands for burrowers, C carnivores, H herbivores, S surface deposit-feeders, F Filter-feeders, M motile, middle S sessile, D discretely motile, J jawed pharynx, X unarmed pharynx and T tentaculate. The basic criteria for this classification are the quantity, the kind of food and the activity they show while consuming their food (Damianidis and Chintiroglou, 2000).

2.7. Data collection–statistical analysis

All samples were collected from the cement piers of each port facility, which were constructed over 15 years ago. The depth of the sampling efforts responded to the average depth of the underwater cement columns of the piers (4 m in st1, 2 m in st2 and 3 m in st3). Samplings were carried out by scuba diving using a modified quadrate sampler of 400 cm^2, which is the minimum necessary surface for a statistically sound investigation on hard substrate (Weinberg, 1978; Stirn, 1981; Chintiroglou and Koukouras, 1992). According to Bakus (1990), three replicates per station were collected from the same diver (third author) at each period, preserved in a 10% formalin solution and transferred to the laboratory for further investigation. Overall samples were available for winter 1994, summer 1994, winter 1995 and summer 1995. During samplings, the physiognomic aspect of the biotops was recorded with an underwater camera in order to obtain data concerning the megafauna component of the biota. All organisms were counted and identified at species level. Common biocoenotic methods were employed to analyze the data (Guille, 1970 and others). The numerical abundance was estimated on a scale of 1 m^2. The estimation of frequency was annual. Shannon (H') and Evenness (J') indices were also calculated. The numerical abundance per sampling period was analyzed using cluster and multidimensional scaling techniques (MDS), based on the Bray–Curtis similarity and log transformed numerical abundances, with Primer package (see Clarke and Warwick, 1994). The significance of the multivariate results was assessed using Anosim test. Furthermore the taxa of polychaeta were analyzed separately in more details using the numerical abundance of (a) species composition and (b) feeding guilds in order to perform a cluster and MDS analysis based on the same principles as mentioned above.

3. Results–Discussion

3.1. Abiotic factors

Hydro-dynamism was measured by checking the corrosion of plaster at each station: st1 = 32.25%, st2 = 19.60% and st3 = 50.79%, so the stations can be ranked as follows: st3 > st1 > st2. Dissolved O_2 showed no significant fluctuations in time at all stations, as its values ranged between 6.5 and 8 ppm. The only exception was at st2, where, as a result of minor renewal and high temperatures during summertime, the values ranged at a lower level (4–5 ppm). The pH values were almost constant to 8 at all stations. Regarding the other abiotic factors, the measured values produced a more or less seasonal pattern. Temperature ranges seasonally from 10.9 to 28.7 °C. The pattern of salinity (35.8–37.9 °C) and conductivity (49.0–52.1 μs cm^{-1}) ranges in a similar way, with the lowest values occurring during summer months. This fact is illustrated by many authors and is due to the influence of the estuary systems and the occurrence of south, southeast winds. As a result, freshwater masses are transferred to the inner part of the bay (Krestenitis et al., 1997; Kamba et al., 2000).

3.2. Classification and description of the assemblages

At that part of the analysis, the meiofauna including the taxonomic group of Nematoda and Copepoda was excluded.

At the first station, the main port of Thessaloniki, a total of 70 species was recorded. In accordance with their frequency (F), 37 of them were named as characteristic, 28 as common and five as rare (Tables 1 and 4). In regards to the mean dominance of the characteristic species as a total, it looks that they cover the 84% of the total abundance. The most representative of the characteristic species were *Stylochus* sp., *Hydroides norvegica*, *Ophiodromus pallidus*, *Staurocephalus rudolphii*, *Corophium acutum*, *Elasmopus rapax*, *Erichthonius brasiliensis*, *Clavelina lepatiformis* and *Styella partita*. Their mean dominance ranges from 4.54% to

Table 1
Mean numerical abundance (mA), frequency (*F*) and mean dominance (mD) values from the main port of Thessaloniki (st1)

Taxa	st1 w94	st1 s94	*F* (%)	st1 w95	st1 s95	*F* (%)	mA	mD	*F* (%)
Eudendrium sp.	*	*	100	*	*	100	*	*	100
Stylochus sp.	58	410	100	85	159	100	59.33	4.553	100
Nematoda	122	2077	83	14	51	66	188.7	14.48	75
Dodecaceria concharum	4	11	83	7	4	83	2.16	0.166	83
Harmothoe spinifera	107	8	100	21	26	100	13.5	1.036	100
H. norvegica	152	517	100	3	39	83	59.25	4.547	92
Hydroides pseudouncinata	39	31	100	21	74	100	13.75	1.055	100
Magalia perarmata	13	3	66	17	5	83	3.17	0.243	75
Nereis succinea	8	24	100	3	17	50	4.33	0.332	75
O. pallidus	42	499	100	313	794	100	137.3	10.54	100
P. dumerilii		11	16	5	20	100	3	0.23	58
Polydora caeca	22	7	83	4	9	66	3.5	0.269	75
Prionospio steenstrupi	17	104	83	21	40	100	15.17	1.164	92
Sabellaria spinulosa	2	32	83	10	10	100	4.5	0.345	92
S. vermicularis	28	48	100	2	14	50	7.67	0.589	75
S. rudolphii	314	195	100	198	158	100	72.08	5.532	100
Terebella lapidaria	55	120	100	29	51	100	21.25	1.631	100
Vermiliopsis infundibulum		30	50	5	14	83	4.08	0.313	67
Arca noae	2	7	66	1	3	50	1.08	0.083	58
Gregaciella sulcata	6	16	83		3	33	2.08	0.16	58
Turboella lia	2	7	66	9	1	50	1.58	0.121	58
Callipalene sp.	11	121	100	6	51	100	15.75	1.209	100
L. savignyi	7		50	8	4	100	1.58	0.121	75
Cymodoce tuberculata	10	21	100	171	43	100	21.25	1.631	100
C. acutum	10	317	83	46	366	100	61.58	4.726	92
E. rapax	4	355	100	439	1019	100	151.4	11.62	100
L. savignyi		539	50	69	161	100	64.08	4.918	85
Pachygrapsus marmoratus	28	233	100	44	98	100	33.58	2.577	100
Pisidia longicornis	67	39	100	26	29	83	13.42	1.03	92
Balanus perforatus		17	50	3	12	66	2.67	0.205	58
B. trigonus	16	198	100	32	132	100	31.5	2.417	100
Bowerbankia sp.	*	*	100	*	*	100	*	*	100
B. stolonifera		*	33	*	*	100	*	*	67
Bryozoa sp.1		*	50	*	*	66	*	*	58
C. intestinalis	18	5	50	124	2	83	12.42	0.953	67
Clavelina lepadiformis	1063		50	121		50	98.67	7.573	50
Pyura microcosmus	3	5	100	3	11	83	1.83	0.14	92
S. partita	9	722	83	172	906	100	150.8	11.57	92
Styella plicata	2	8	66	1	68	66	6.58	0.505	66

11.62%. It should be noted that the ascidian *Ciona intestinalis* and the three Bryozoan species, whose numerical abundances were relatively low, are very frequent in our samples. This fact is attributed mainly to the sampling surface of the quadrate sampler used for the purposes of this research, which concerns mostly the macrofauna species. In order to cover the distribution of some megafauna species as those above, a surface from 0.5 × 0.5 to 1 × 1 m^2, in dependence with the size of the target species, would be more preferable (Stirn, 1981).

At the marina of Kalamaria (st2), 74 species were recorded. Overall 41 were classified as characteristic with a total mean dominance that exceeded 99% (Tables 2 and 4). The most dominant species were *H. norvegica*, *Serpula vermicularis*, *Leptochelia savignyi*, *C. acutum*, *E. rapax*, *E. brasiliensis*, *C. lepatiformis* and *S. partita* (mean dominance ranging from 2.4% to 29.81%). The presence of *C. intestinalis* was low, when compared with st1.

At the fishery port of N. Michaniona, 108 species were found, 41 of which were characteristic (total mean dominance over 97%) as Tables 3 and 4 show. From these species, *Aiptasiogeton pellucidus*, *Exogone gemmifera*, *Scoletoma funchalensis*, *L. savignyi*, *C. acutum*, *Corophium sextonae*, *E. rapax*, *E. brasiliensis* and *Balanus eburneus* contribute the most to the total abundance (mean dominance ranging from 1.5% to 29.8%).

Besides the differences observed at the three stations, it is generally true that the taxonomic group of Polychaeta prevails in all the examined port assemblages, with a percentage ranging from 41% to 50%. Next follow the Crustacea (20–24%) and the Mollusca (10%). These results, presented in Table 4, are in accordance with relevant studies in the

Table 2
Mean numerical abundance (mA), frequency (*F*) and mean dominance (mD) values from Kalamaria harbor (st2)

Taxa	st2 w94	st2 s94	*F* (%)	st2 w95	st2 s95	*F* (%)	mA	mD	*F* (%)
Cliona sp.	*	*	66	*	*	83	*	*	75
Eudendrium sp.		*	16	*	*	83	*	*	50
A. pellucidus	99	199	100	37	499	100	69.5	1.966	100
Stylochus sp.	18	47	100	30	602	100	58.08	1.643	100
Nematoda	35	53	100	24	9	66	10.08	0.285	83
Oligochaeta	6	11	66	6	15	66	3.17	0.09	67
D. concharum	14	3	66	3	17	83	3.08	0.087	75
E. gemmifera	38	63	100	93	54	100	20.67	0.585	100
H. spinifera	2	2	50	4	1	50	0.75	0.021	50
Heterocirrus alatus	21	13	100	37	13	100	7	0.198	100
Heterocirrus bioculatus	148	32	83	70	67	100	26.42	0.747	92
Heteromastus filiformis	24	39	83	110	17	100	15.83	0.448	92
H. norvegica	40	122	100	133	1170	100	122.08	3.453	100
H. pseudouncinata	69	65	100	44	43	100	18.42	0.521	100
M. perarmata	62	15	100	23	1	66	8.42	0.238	83
N. succinea	1	20	66		2	33	0.25	0.007	50
O. pallidus	1	10	50	25	31	100	5.58	0.158	75
Phyllodoce madeirensis	4	2	83	4	9	100	1.58	0.045	92
P. caeca	63	28	100	43	15	100	12.42	0.351	100
P. steenstrupi	28	42	100	37	23	100	10.83	0.306	100
S. vermicularis	7	344	83	110	786	100	103.92	2.94	92
S. rudolphii	105	36	100	94	8	100	20.25	0.573	100
T. lapidaria	52	22	100	44	43	100	13.42	0.38	100
Tharyx marionii	2	10	50	4	1	50	1.42	0.04	50
V. infundibulum	66	141	100	85	34	100	27.17	0.769	100
Modiolus barbatus	6	9	66		6	33	1.75	0.05	50
Cyclops sp.	2	4	50	2	1	50	0.75	0.021	50
L. savignyi	4213	2485	100	3730	2221	100	1054.1	29.82	100
Tanais cavolinii	7	2	66	6	52	66	5.58	0.158	67
C. tuberculata	43	415	100	67	37	100	46.83	1.325	100
C. acutum	15	3798	83	252	6184	100	853.33	24.14	92
E. rapax	177	2667	100	548	670	100	338.5	9.576	100
E. brasiliensis	7	4351	100	38	6	83	366.83	10.38	92
P. marmoratus	40	19	83	26	20	100	8.75	0.248	92
P. longicornis	13	19	83	8	8	100	4	0.113	92
B. perforatus	1	1	33	6	23	83	2.58	0.073	58
Bowerbankia sp.	*	*	83	*	*	83	*	*	67
C. lepadiformis	648		50	1388		50	186.33	5.271	50
P. microcosmus	1	7	50	2	5	83	1.25	0.035	67
S. partita	234	50	100	136	610	100	85.83	2.428	100
S. plicata	16		50	2	23	66	3.33	0.094	58

Western Mediterranean Sea. The only exception seems to be the cases of assemblages affected by thermal pollution, where the prevailing taxa are Mollusca followed by Polychaeta and Crustacea (Bellan-Santini et al., 1976). For these reasons, the majority of the relevant information focuses on polychaetes and crustaceans.

Reviewing the contemporary bibliography, we can consider the species *S. rudolphii*, *Platynereis dumerilii*, *H. norvegica*, *Leptochelia savingnyi*, *C. intestinalis*, *Nebalia* sp., *S. partita*, *Balanus trigonus* and *Bugula stolonifera* as common components of the assemblages of polluted ports in the Mediterranean (Pérès and Picard, 1964; Bellan-Santini, 1968; Bellan-Santini et al., 1976; Bellan, 1980; Bitar, 1982; Desrosiers et al., 1986; Baxevanis and Chintiroglou, 2000, and others). The rest of the species found in our research was among the commonly recorded from the different facies of the assemblage of photophilic algae.

After a close examination of the faunistic components of the three examined stations, we can classify them according to Pérès and Picard (1964) and Bellan-Santini et al. (1994). The dominant species at st1 and st2 were the ascidians *C. intestinalis*, *C. lepatiformis*, *S. partita*, the amphipods *E. rapax*, *C. acutum*, *E. brasiliensis*, the polychaetes *S. rudolphii*, *H. norvegica*, *O. pallidus* and the green algae *Ulva rigida*. So both assemblages can be placed among the hard substrate assemblages of polluted ports. In st3, the situation is a little more complicated, since it corresponds to the assemblages of photophilic algae as well as those of semi-polluted ports. The presence of the sea anemone *A. pellucidus*, the great numbers of Syllidae polychaetes (9) and the

Table 3
Mean numerical abundance (mA), frequency (*F*) and mean dominance (mD) values from the fishery port of N. Mihaniona (st3)

Taxa	st3 w94	st3 s94	*F* (%)	st3 w95	st3 s95	*F* (%)	mA	mD	*F* (%)
Eudendrium sp.	*	*	100	*	*	83	*	0	92
A. pellucidus	1538	3455	100	2043	1112	100	679	29.83	100
Leptoplana sp.	7	21	66	17	19	100	5.33	0.234	82
Stylochus sp.		12	50	2	14	83	2.33	0.102	67
Turbellaria sp.1	4		16	3	32	100	3.25	0.143	58
Nematoda	54	92	83	117	82	100	28.75	1.263	92
Oligochaeta	45	2	66	16	26	83	7.42	0.326	75
D. concharum	4	11	100	42		50	4.75	0.209	75
E. gemmifera	322	1245	100	503	483	100	212.8	9.348	100
Glycera sp.					2	33	0.17	0.007	17
Grubeosyllis sp.	3	9	50	3	8	66	1.92	0.084	58
H. bioculatus	17	28	100	73	16	100	11.17	0.491	100
H. filiformis	4	7	50	16	10	66	3.08	0.135	58
H. norvegica	6	18	50	186	87	100	24.75	1.087	75
H. pseudouncinata	15		50	4	15	83	2.83	0.124	67
Kefersteinia cirrata	2		16	6	5	83	1.08	0.047	50
Lumbrinereis gracilis	10	23	100	15	19	100	5.58	0.245	100
M. perarmata	11	3	100	10	17	66	3.42	0.15	83
P. madeirensis	4	1	33	11	3	66	1.58	0.069	50
P. caeca	7	9	100	26	4	100	1.67	0.073	100
Polydora hoplura	3	8	50	31	12	100	4.5	0.198	75
Potamilla reniformis	2	3	33	6	2	66	1.08	0.047	50
P. steenstrupi		12	50	6	11	50	2.42	0.106	50
S. spinulosa	1	8	50	7	5	66	1.75	0.077	58
S. funchalensis	1083	336	100	769	481	100	222.4	9.772	100
S. vermicularis	15	26	83	84	196	100	26.75	1.175	92
Syllis hyalina	5	9	100	9	6	66	2.42	0.106	83
Mytillus galloprovincialis	22	41	83	12	3	83	6.5	0.286	83
Phoxichilidiidae	38	18	100	9	8	83	6.08	0.267	92
*Cyclops*sp.	12	111	83	28	12	83	13.58	0.597	83
L. savignyi	832	692	100	71	727	100	193.5	8.502	100
C. tuberculata	42	16	100	22	6	100	7.17	0.315	100
Corophium acherusicum	15	8	100				1.92	0.084	50
C. acutum	623	754	100	399	2597	100	364.4	16.01	100
C. sextonae	321	978	100	12	41	100	112.7	4.95	100
E. rapax	274	709	100	91	420	100	124.5	5.47	100
E. brasiliensis	240	178	100	1	36	50	37.92	1.666	75
Stenothoe cavimana	24		50	35		50	4.92	0.216	50
P. longicornis	4	14	83		2	16	1.67	0.073	50
B. eburneus	199	353	100	111	123	100	65.5	2.878	100
Phallusia fumigata	3	9	83	7	12	100	2.58	0.113	92
S. partita		3	50	8	14	66	2.08	0.091	58
S. plicata		2	16	8	7	66	1.42	0.062	42

increasing flora diversity (for example, *Bryopsis pennata*, *Ceramium fastigiatum*, *Cladophora prolifera*, *Dictyota dichotoma*, *Lomentaria articulata*), possibly shows that it represents an intermediate phase between the two aforementioned assemblages.

We can conclude that the fauna of the artificial hard substrates in ports is composed by a complex of species from the photophilic algae assemblage, which are resistant to a variety of pollution sources, always in dependence with their different biotic interactions in space and time. According to

Table 4
Number of species classified among the three categories according to their frequency and total number of species per station per year

	st1 1994	st1 1995	st2 1994	st2 1995	st3 1994	st3 1995
Characteristic	41	44	46	46	44	52
Common	12	14	11	6	19	13
Rare	8	8	13	11	28	22
Total	61	66	70	63	91	87

Table 5
Numerical abundance, species richness, Shannon–Weaver and Evenness calculations per sampling station

Sampling station	Numerical abundance	Species richness	Shannon–Weaver (H')	Evenness (J')
St1	15 643	71		
Winter 1994	2291	45	3.117	0.574
Summer 1994	6811	55	3.684	0.631
Winter 1995	2064	51	3.848	0.678
Summer 1995	4477	59	3.714	0.631
St2	42 294	75		
Winter 1994	6403	62	2.355	0.400
Summer 1994	15 213	60	2.794	0.483
Winter 1995	7314	54	2.652	0.457
Summer 1995	13 364	55	2.503	0.437
St3	26 297	105		
Winter 1994	5872	68	3.389	0.561
Summer 1994	9461	73	3.298	0.534
Winter 1995	5100	77	3.263	0.524
Summer 1995	5864	68	3.192	0.524
Total	84 234	125		

Bellan-Santini (1968), three stocks of species are representative, the first includes species from the photophilic algae assemblage, the second species-indicators of pollution and the third species that are widely distributed and they appear to port assemblages. The species of the above groups differentiate in a geographical scale. It should be added here that the classification of the Polychaetofauna in a broader sea region could be distinguished in 11 stocks of species (Bellan, 1980). Some of the species that belong to these stocks seem to be included in this study too. *H. norvegica*, for example, showed a gradual decrease in abundance from station 1 (heavily polluted site) towards station 3 (lightly affected area). On the other hand, the species *S. rudolphii*, which is typical in polluted areas, did not occur at station 3, though its abundance increased gradually from station 2 towards station 1. Another species with similar interest is *O. pallidus*, for which there is not much evidence about its occurrence in hard substrata (that contain confined sediment) or about its relationship with pollution. All of the three aforementioned species can be included in the stock of pollution indicators (see Bellan, 1980). Another stock of species that are sensitive to increasing pollution includes the species of the genus *Syllis* and the species *S. funchalensis* (common in photophilic algae and Maerl assemblages) (see Bellan, 1964).

3.3. Diversity, abundance and similarity

Overall 84 234 individuals were counted, belonging to 125 species. The distribution of individuals and species per sampling station and, also, the results from Shannon–Weaver (H') and Evenness (J') calculations are presented in Table 5. Obviously the lowest values for both indices appear at st2. Many authors mention that H' values are representative for the 'healthiness' of an assemblage. The stability of H' and J' at each station through time, indicates that the above assemblages are long-standing, well aged and fitted to the local conditions. The index depends on two factors: the number of species and their abundance. That's why the local extinction of species by pollution may be masked by little or no change in the value of H', so these indices must be crosschecked with other features of the assemblages. When the numerical abundance and the species' richness modifies analogically, the index gains high values. This is the case for st1. The numerical abundance is lower than at the other stations but the same thing applies for species' richness. As a result, the index gains values similar to st3, despite the fact that the number of species at the latter is much greater (so does the numerical abundance). The numerical abundance at st2 was high but the number of species was low. Consequently, H values were low. At that point, we should state that numerical abundance values fall during wintertime. This fact is quite common and must be related to some biological interactions, mainly the reproductive strategies of the faunistic components.

The results of cluster and MDS analysis are depicted in Fig. 2. The stress value for the two-dimensional MDS plot was 0.03, indicating a proper group separation. The results of Anosim (R = 0.944, significance level is 0.2%) indicate discrimination between the groups of samples. Therefore, the cluster and the MDS analysis are confirmed.

From these figures, we observe three main groups at a 60% similarity level. Each group was composed by the samples from each station. By looking closer to the first group matching all the samples from the port of Thessaloniki, we can detect a clear separation of the sample from winter 1994. This sample relates to that of winter 1995, while the summer samples from both years are classified together at the same similarity degree. At the second group including samples from Kalamaria harbor, the pattern is undoubtedly seasonal. Summer samples are classified together. Winter samples follow the same rule in an even higher similarity degree. At the third group counting samples from N. Michaniona port, the pattern is rather annual than seasonal. Two subgroups are detectable, the one containing all the samples from 1994, while the other from 1995. We can also notice that the likeness is higher during 1995.

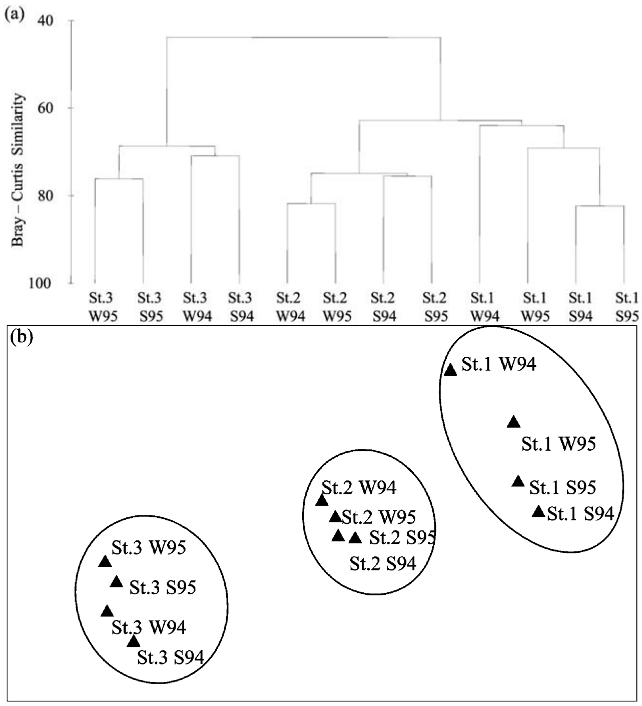

Fig. 2. Results of (a) cluster analysis and (b) MDS based on Bray–Curtis similarity index, during 2 years of survey.

From the above it is evident, in terms of species composition, that st3 differentiates from the others. The loss of the seasonal pattern at st3 may indicate some kind of disturbance. Indeed a new dock was constructed during the first months of 1995. This construction acts as an obstacle to water movement. The currents are altered and so does the sedimentation rate. This fact is reflected in our results. It seems to lead to an impoverishment of the assemblage that naturally occurs.

4. Results using the taxa of Polychaeta

Polychaetes are among the most frequent and abundant marine benthic organisms in man-made harbors (Fauchald and Jumars, 1979; Barnard and Reish, 1959) and are also among the most 'species-rich' groups. There are many authors who suggest that they can play a key role to biomonitoring studies (Reish, 1978; Bellan, 1980; Wenner, 1988; Warwick, 1993). We attempt to test this hypothesis in our data using their numerical abundance, on the one hand based on species composition and on the other hand on their feeding guilds to perform a similarity analysis. Polychaetes' feeding guilds are fairly known (Fauchald and Jumars, 1979). When an environmental disturbance occurs, a particular trophic group will dominate, depending on the type of disturbance (Desrosiers et al., 1986). Consequently we can use their trophic relation, which is a clearly functional characteristic, for the purposes of environmental impact studies.

The results of the cluster and MDS analysis for both cases are presented in Fig. 3. The stress value for the two-dimensional MDS plot was 0.04 (c) and 0.05 (d), indicating a very good group separation in both cases. The results of Anosim (R = 0.896 significance level is 0.2% for the feeding guilds case and R = 0.910 significance level is 0.2% for the species composition) indicate discrimination between the groups of samples, confirming the cluster and the MDS analysis.

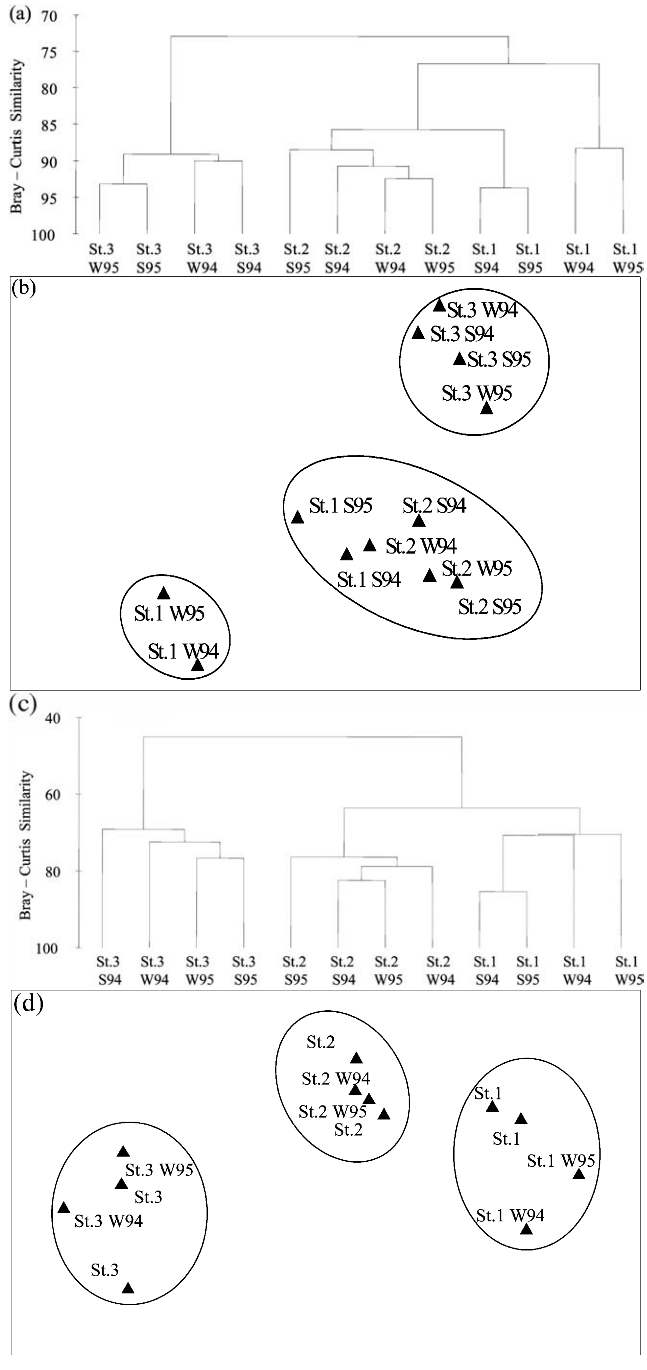

Fig. 3. Cluster and MDS analysis based on the numerical abundance of the feeding guilds of polychaetes (a and c) and on the numerical abundance of polychaetes species (b and d), based on Bray–Curties similarity index.

We can easily perceive that the configurations produced are very similar in both cases. Indeed all samples from each station are clustered together. We must comment the fact that the similarity is extremely high in the case of feeding guilds and this changes the image a little. If we compare Fig. 2 with Fig. 3, we find no differences among the dendrogrammes and the MDSs constructed from numerical abundances per species composition data. But we do find minor differences in the case of feeding guilds where we can detect once again three major groups in 85% similarity level. The first one contains the winter samples from the port of Thessaloniki, the second all the samples from Kalamaria plus the summer samples from Thessaloniki and the third all the samples from N. Michaniona. This 'change of place' of summer samples from the port of Thessaloniki may be attributed to the environmental conditions during the summer months, especially to the low hydro-dynamism. The high temperatures and the limited water renewal occur in summer, so the profile of st1 is very closely linked to st2, a fact that is reflected in our data by a change through the feeding guilds of polychaetes in favor of filter-feeders. We can also mark an increase of the carnivores' percentage, mainly caused by the species *O. pallidus*. This species duplicates its numerical abundance during summer months, probably due to a successive reproductive period, but also to the fact that this species is capable of feeding on diatoms, bacteria and detritus, acting as a deposit-feeder (Fauchald and Jumars, 1979) and consequently favored by the environmental conditions during the hot season. A closer examination of the second group reveals three subgroups including (1) the summer samples from the port of Thessaloniki, (2) one summer sample from Kalamaria and (3) the rest of the samples from Kalamaria. The seasonal pattern is kept in all three cases in st1 (port of Thessaloniki), though a little altered in st2 (Kalamaria harbor) (when we used the feeding guilds data), and completely lost in st3 (N. Michaniona) where it is replaced by an annual pattern. Therefore, we can conclude that the taxa of polychaeta can be acceptably used for the description of the general terms of these three assemblages producing the same groups, even when we consider them as one functional group.

5. Conclusion

The facts that were recorded during this study led to conclusions which have been more or less reported by many researchers (Bellan, 1980; Wenner, 1988; Bellan-Santini et al., 1994; Baxevanis and Chintiroglou, 2000; Damianidis and Chintiroglou, 2000 and others): (a) there is no adequate information on the structure and function of the benthic assemblages on hard substratum in ports, (b) the qualitative composition of these assemblages is significantly even, as far as the pollution indicators are concerned, (c) the differentiations that were observed, at both qualitative and quantitative levels, should be attributed to different constructional background, to human intervention (e.g. extension of ports) and, also, to the different operational activities (e.g. tourism, commercial docks etc.) at each port and, finally, (d) the biotic interactions between the living organisms (e.g. space competition, feeding adaptations and habits etc.) play a significant role for these differentiations.

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