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ORIGINAL ARTICLE

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Peracarida populations of hard substrate assemblages in ports of the NW Aegean Sea (eastern Mediterranean)

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Abstract This study deals with the structure of Peracarida populations in four ports in the NW Aegean Sea, Greece, and with the degree this structure is influenced by the particular biotic and abiotic conditions that prevail in the ports. Quantitative samples were taken during summer and winter in two successive years from artificial hard substrates and were analysed using common biocoenotic methods. The examination of approximately 81,250 specimens revealed the presence of 24 Peracarida species, the most dominant of which were *Corophium acutum*, *Leptochelia savignyi* and *Elasmopus rapax*. All species are very common and have been reported from many sites and assemblages in the N Aegean Sea. The ratios of certain Peracarida genera are discussed as possible indicators of environmental health that may be used in long-term biomonitoring programmes on the impact of pollution in harbours.

Keywords Peracarida · Hard substrate · Ports · Pollution · Aegean Sea

Introduction

The estimation of marine pollution has become a priority subject in recent years (Thomas 1993). Approaches to this problem have been manifold. In polluted ports, high abundance of species usually coincides with low diversity and vice versa. According to Bellan-Santini et al. (1994), this is particularly obvious for oligotrophic systems such as the Mediterranean Sea, where low abundance and high diversity are normally observed.

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The biodiversity in ports is not yet fully understood, because knowledge of the structure and function of artificial hard substrate assemblages in polluted harbours is limited (Baxevanis and Chintiroglou 2000). This is due both to the difficulties involved in quantitative sampling, and to the complexity of the abiotic factors which affect the assemblages established on artificial substrates (Bellan and Pérès 1994). Furthermore, biodiversity seems to be increased in ports, which causes additional difficulties in drawing reliable conclusions (Baxevanis and Chintiroglou 2000). Generally, assemblages in ports (e.g. Marseilles) are considered to be assemblages of invertebrates in heavy polluted waters (Pérès and Picard 1964; Bellan-Santini 1968, 1969). Relevant information has been given by Bellan-Santini (1981, 1983), Bellan-Santini and Desrosiers (1976, 1977), Bellan-Santini et al. (1994), Zavodnik and Zavodnik (1978), Tursi et al. (1982, 1984), Hargrave and Thiel (1983) and Leewis and Waardenburg (1989). The characteristics of these assemblages are related to the environmental conditions as well as to the organisms' adaptability (Baxevanis and Chintiroglou 2000; Damianidis and Chintiroglou 2000).

Owing to their ecological importance, numerical abundance and sensitivity to a number of pollutants, Peracarida have been known as sensitive environmental indicators (Hart and Fuller 1979) and thus have been used as primary biomonitors in various regions (Reish and Barnard 1979; Meijering 1991; Thomas 1993). The aim of this study was to provide information on the structure of Peracarida (Crustacea) populations of artificial hard substrate assemblages in four ports in the NW Aegean Sea, in order to set up a basis for future biomonitoring activities.

Methods

Study area

Four stations were selected in the NW Aegean Sea: ST1 = port of Thessaloniki, ST2 = fishing port of Kalamaria, ST3 = fishing port of N. Michaniona (largest in Greece) and ST4 = tourist marina of

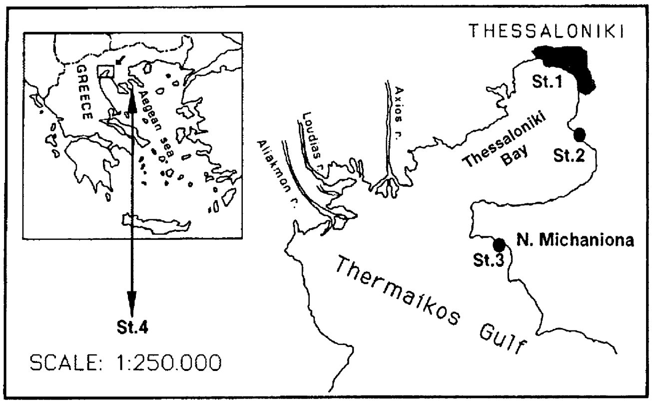

Fig. 1 Map showing sampling stations: *ST1* port of Thessaloniki; *ST2* EOT marina in Kalamaria; *ST3* fisheries port in N Michaniona; *ST4* Porto Karras Marina in Chalkidiki

Porto Karras (Fig. 1). The choice was based mainly on the stations' location in the bay of Thessaloniki and their distances from the main sources of pollution in Thermaikos Gulf. ST1 and ST2, located on the NW coasts of the gulf, are influenced by sewage produced by the neighbouring industrial and urban area of the city. ST3, located on the NE side of Thermaikos Gulf, receives only local urban waste. However, organic pollution is evident, originating from material of the estuaries system of the Axios, Loudias and Aliakmonas rivers, and also from fishing boat waste (Baxevanis and Chintiroglou 2000; Kamba et al. 2000). Lastly, ST4, located at Toroneos Gulf, is less affected by human activities, which are restricted to the summer tourist season: the station served as a reference point.

There is much information on the concentration of chemicals (nitrates, nitrites, ammonium, phosphates, silicates) in Thermaikos gulf (Samanidou et al. 1987; Nikolaidis and Moustaka-Gouni 1990; Stergiou et al. 1997). Nitrates and ammonium, in particular, show significant seasonal fluctuations, with a maximum during winter and a minimum in summer. According to Samanidou et al. (1987), nutrients are highly concentrated near Thessaloniki harbour (ST1 and ST2) where the majority of urban sewage was discharged untreated until 1998**.**

The assemblages at ST1 and ST2 have been classified as hard substrate assemblages of heavily polluted ports (Pérès and Picard 1964; Bellan-Santini et al. 1994). The flora is dominated by *Ulva rigida* C.Ag, while the dominant faunal species are the ascidians *Ciona intestinalis* Linnaeus 1767 and *Clavelina lepadiformis* Muller 1776, and the polychaete *Schistomeringos rudolphii* Delle Chiaje 1828 (unpublished data). The assemblage at ST3 resembles that of photophilic algae and also that of semi-polluted ports (see Pérès and Picard 1964; Bellan-Santini 1969, 1981; Bellan et al. 1988). The presence of the sea anemone *Aiptasiogeton pellucidus* (Hollard, 1848), the high number of syllid polychaetes, and also the increased diversity of the flora [*Bryopsis* sp., *Ceramium* sp., *Cladophora prolifera* (Roth) Kutz., *Dictyota dichotoma* (Huds.) Hauck, *Lomentaria* sp.], indicate that the assemblage at ST3 represents an intermediate state between the assemblages at ST1 and ST2 on the one hand and at ST4 on the other. Finally, a typical facies of the photophilic algae assemblage (facies of *Stypocaulon scoparium* Kutzing) has been found at ST4 (see Pérès and Picard 1964; Bellan-Santini 1969; Taramelli-Rivosecchi 1969; Tsuchiya and Bellan-Santini 1989).

Sampling techniques

Sampling was carried out by scuba diving using the quadrate/sampler designed by Chintiroglou and Koukouras (1992). The surface area covered by the sampler was 400 cm^2. For each sampling site and period, three to five replicates were taken in order to achieve the minimum necessary area for a statistical investigation of hard substrates (Weinberg 1978; Stirn 1981; Chintiroglou and Koukouras 1992). The samplings were performed in winter (W) and summer (S) over two successive years (1994–1995). All samples were collected from the cement piers of the port facilities, which had been constructed more than 15 years previously. Samples were taken at a depth which corresponded to the average depth of the underwater cement columns of the piers (5 m at ST1, 2 m at ST2 and ST4, and 3 m at ST3). Samples were preserved in 10% formalin and transferred to the laboratory for further investigation. Specimens of the class Peracarida were counted and identified to species level.

Abiotic parameters

Physico-chemical factors (salinity, conductivity, water clarity, dissolved oxygen and temperature) were measured monthly at each sampling site. They were made using micro-electronic equipment [WTW salinity-conductivity-O_2 meter (Hanna Instruments, Vila do Conde, Portugal), Lovibond Checkit pH-meter (Hanna Instruments)]; water clarity was determined using the Secchi disc (KC Denmark, Research Equipment, Silkeborg, Denmark). Furthermore, the total hydro-dynamism was measured, based on the corrosion of plaster in the water (Kaandorp 1986; Kluijver and Leewis 1994).

Data analysis and statistics

Common biocoenotic methods were employed to analyse the data (Bellan-Santini 1981; Damianidis and Chintiroglou 2000). Hence, the numerical abundance (*N*) on a scale of 1 m^2, the mean dominance (*D*), and the frequency (*f*) were estimated. Also, Shannon-Weaver's (H') and Pielou's Evenness (J') were calculated on a $\log_2$ basis (Daget 1979). The pollution indicator ratio of the abundance of certain genera of Peracarida, as proposed by Bellan-Santini (1981), was calculated in order to test its efficiency in the present case study.

The data obtained from different sampling stations were analysed using cluster and multidimensional scaling techniques, based on the Bray-Curtis similarity and log transformed numerical abundances, using the PRIMER package (see Clarke and Green 1988; Clarke and Warwick 1994). The significance of the multivariate results was assessed using the ANOSIM test. SIMPER analysis was applied in order to identify the percentage contribution of each species to the overall similarity within a site and to the dissimilarity between sites (Clarke 1993). The above analyses were performed to examine the similarity degree of samples in both space and time.

Results

Abiotic factors

Hydro-dynamism at the stations was measured by checking the corrosion of plaster. The stations ranked as follows: ST3(50.8%)>ST1(32.3%)>ST2(19.6%)>ST4(10%). Water clarity was always higher in winter than in summer and the stations ranked as follows: ST4>ST3>ST1>ST2.

At all stations, dissolved O_2 showed no significant fluctuations over time. The range was 6.5–8 ppm, with the exception of ST2: as a result of minor exchange and high temperatures during summer, the values at ST2 were lower (4–5 ppm). The pH values were almost the same at

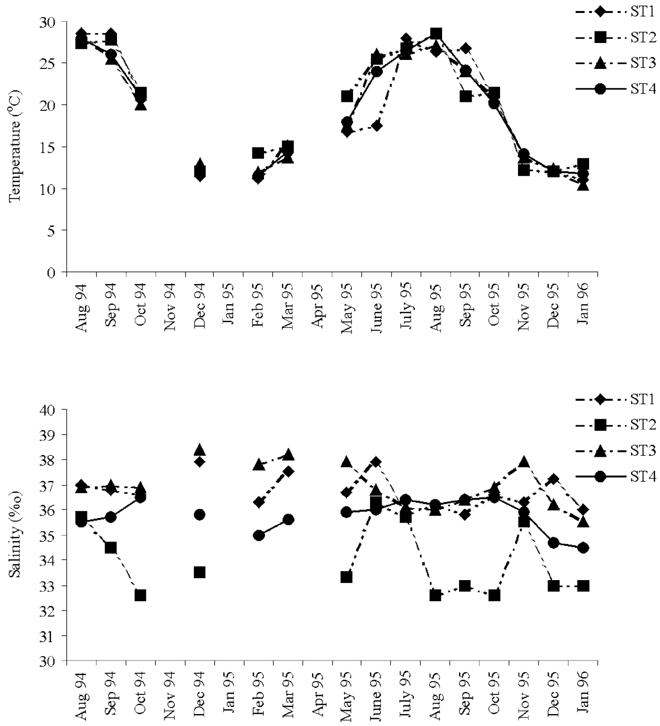

Fig. 2 Temperature and salinity at the sampling stations over the study period

all stations in both sampling periods (pH≈8). Other abiotic factors showed a more or less marked seasonal pattern (Fig. 2).

Composition of peracarid populations

A total of 81,250 peracarid individuals were counted and identified as 24 species belonging to four taxa (18 Amphipoda, two Isopoda, three Tanaidacea and one Cumacea). The most abundant species were *Corophium acutum*, *Leptochelia savignyi* and *Elasmopus rapax*, followed by *Ericthonius brasiliensis*, *Corophium sextonae* and *Cymodoce* sp. The rest of the species occurred only sporadically (Tables 1, 2).

Ratios between peracarid genera as pollution indicators

According to the relevant literature, species of the genera *Corophium*, *Erichthonius* and *Leptochelia* often dominate under polluted conditions. They are commonly referred to the characteristic of organic rich environments. In contrast, species of the genera *Tanais* and *Elasmopus* usually occur in clear waters. All of the above genera, which are characteristic inhabitants of harbours, proved to be unevenly distributed to our sampling stations. Bellan-Santini (1981) proposed that the ratio of the abundance (or dominance) of certain peracarid genera might represent a reliable indicator of pollution. Specifically, the author suggested that the ratio of the mean dominance of the genera *Jassa* and *Hyale* reflects the degree of pollution (the value is higher under increased pollution), at least for the western Mediterranean Sea. At our study sites, however, *Hyale* was not recorded at all and *Jassa* only sporadically. It seems that the composition of peracarid populations in the NW Aegean is quite different from that in the western Mediterranean. As Barnard (1958) stated: "different harbours may include different species, even when they are only few miles down-coast". Instead of the ratio proposed by Bellan-Santini (1981), we calculated the ratio of the sum of the mean dominance (D) of the genera *Corophium*, *Erichthonius* and *Leptochelia*, and the sum of D of *Elasmopus* and *Tanais*, to test the hypothesis that this ratio reflects the water condition at the four sampling sites. The ratios were as follows: 1.4 at ST1; 7.93 at ST2; 5.66 at ST3; and 1.3 at ST4, suggesting increased pollution in the following order: ST2>ST3>ST1>ST4. This result, however, does not correspond to the actual situation. The value at ST1 was strongly influenced by the presence of *E. rapax* during 1995. The occurrence of this species is not clearly related to pollution: the species has been recorded from both ports and photophilic algae assemblages (Kocatas 1978). Its presence is related with low hydro-dynamism (Barnard 1958) which favours nontubicolous species. In 1994, all the Peracarida collected were tubicolous, demanding turbid water that carries along organic and mineral particles for tube construction. The ratio at ST4 was higher than expected, due to the high numbers of *C. acutum* in winter 1994, after a successful reproductive period leading to a temporary peak in population density (Gouvis 1988).

Diversity-abundance: similarity of peracarid populations

The largest number of species occurred at ST3 (N_S=15), followed by ST4 (N_S=11), while fewer species were recorded at ST1 and ST2 (N_S=5 and N_S=6, respectively). The number of species decreased from 1994 to 1995 at ST3 and ST4 but remained stable at ST1 and ST2. At ST1, ST2 and ST3, the number of individuals was generally higher in summer, while the opposite was observed at ST4.

Shannon (H') values varied between 0.39 (ST2 W94) and 2.39 (ST3 W94), while evenness ranged from 0.15 (ST2 W94) to 0.96 (ST1 W94). The above indices showed a similar pattern and were strongly influenced by the increased numerical abundance of some species.

The affinity of samples is shown in Fig. 3. Both analyses [cluster and non-metric multidimensional scaling (mds)] indicate a separation of the samples into three main groups of about 50% similarity degree. Group A contains all samples from ST4, group B the 1994 winter samples from ST1, and group C the remaining samples from ST1 as well as all samples from ST2 and ST3. However, at about 60% similarity degree, five groups can be distinguished: group A comprising the 1995 summer

Table 1 Peracarid species found at the sampling stations during 1994. *f* Frequency, *D* mean dominance. Rows in *bold* refer to the most dominant species

	ST1 W94		ST2 W94		ST3 W94		ST4 W94		ST1 S94		ST2 S94		ST3 S94		ST4 S94	
	f	*D*	*f*	*D*	*f*	*D*	*f*	*D*	*f*	*D*	*f*	*D*	*f*	*D*	*f*	*D*
Amphithoe ramondi	0	0	0	0	0	0	4	0.54	0	0	0	0	0	0	2	4.57
Corophium acherusicum	0	0	0	0	3	0.63	0	0	0	0	0	0	2	0.18	0	0
C. acutum	**2**	**32.3**	**4**	**0.36**	**3**	**26.11**	**4**	**81.84**	**5**	**28.0**	**5**	**30.9**	**3**	**24.8**	**5**	**11.9**
C. insidiosum	0	0	0	0	0	0	4	1.37	0	0	0	0	0	0	1	0.09
C. sextonae	**0**	**0**	**5**	**3.32**	**3**	**13.45**	**4**	**0.31**	**0**	**0**	**0**	**0**	**3**	**30.06**	**2**	**0.17**
Corophium sp.	0	0	0	0	0	0	1	0.66	0	0	0	0	0	0	0	0
Dexamine spiniventris	0	0	0	0	0	0	4	0.49	0	0	0	0	0	0	1	0.17
D. spinosa	0	0	0	0	0	0	4	0.95	0	0	0	0	0	0	5	3.3
Elasmopus rapax	**3**	**12.9**	**4**	**0.11**	**3**	**11.48**	**0**	**0**	**5**	**25.3**	**5**	**21.1**	**3**	**15.51**	**5**	**10.27**
Ericthonius brasiliensis	0	0	0	0	3	10.06	0	0	5	44.9	5	28.5	3	5.67	1	0.17
Jassa marmorata	0	0	0	0	1	0.17	0	0	0	0	0	0	1	1.8	0	0
Leucothoe serraticarpa	0	0	0	0	0	0	0	0	0	0	0	0	2	0.28	0	0
L. spinicarpa	0	0	0	0	1	0.04	0	0	0	0	0	0	1	0.03	0	0
Liljeborgia dellavallei	0	0	0	0	0	0	0	0	0	0	0	0	1	0.03	0	0
Maera inaequipes	0	0	0	0	0	0	0	0	0	0	0	0	1	0.06	0	0
Stenothoe cavimana	0	0	0	0	3	1.01	1	0.02	0	0	0	0	0	0	1	0.26
S. monoculoides	0	0	0	0	2	0.38	0	0	0	0	0	0	1	0.03	0	0
Perioculoides aequimanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymodoce sp.	3	32.3	5	1.70	3	1.76	0	0	5	1.76	5	3.37	3	1.02	0	0
Iphinoe sp.	0	0	0	0	1	0.04	0	0	0	0	0	0	1	0.03	0	0
Leptochelia savignyi	**3**	**22.5**	**5**	**94.4**	**3**	**34.87**	**495**	**8.39**	**1**	**0.04**	**5**	**16.1**	**3**	**20.4**	**5**	**31.68**
Tanais cavolinii	0	0	4	0.13	0	0	0	0	0	0	1	0.03	0	0	5	37.42
T. dulongii	**0**	**0**	**0**	**0**	**0**	**0**	**320**	**5.43**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Paranthura nigropunctata	0	0	0	0	0	0	0	0	0	0	0	0	1	0.1	0	0
Number of individuals (*N*)	31		7,152		2,386		5,898		2,396		21,890		3,237		1,149	
Number of species	4		6		12		10		5		6		15		11	

samples from ST4, group B the remaining samples from ST4, group C the 1994 winter samples from ST1, group D the remaining samples from ST1 as well as all samples from ST2, and group E all samples from ST3. The stress value for the two-dimensional mds configuration is 0.06, indicating a very good ordination of samples (Clarke and Warwick 1994). The performance of a one-way ANOSIM test gave global R of 0.798 at a significance level of $P<0.001$. Thus, the four sites are separate. Further examination in order to localize the differences between the stations using a pair-wise test confirmed the separation of ST3 and ST4 (R ranges from 0.89–1, $P=0.029$), while ST1 proved to be related to ST2 (R 0.58, $P=0.029$).

Group B showed an average similarity of 34.9%. According to SIMPER analysis, two species alone (*L. savignyi* and *Tanais dulongi*) were responsible for 60% of the average similarity and four species (the above plus *C. acutum* and *Amphithoe ramondi*) for 90%. Group D reached an average similarity of 29.4%. *E. rapax* and *L. savignyi* alone covered 60% of this value while four species (the above plus *C. acutum* and *E. brasiliensis*) covered 90%. Group E reached an average similarity of 44. 9%: *C. acutum* and *L. savignyi* were responsible for 60% of this value, whereas four species (the above plus *E. rapax* and *C. sextonae*) covered 90%. For groups A and C, relevant results could not be obtained, because these groups contained only one sample each.

Table 2 Peracarid species found at the sampling stations during 1995. *f* Frequency, *D* mean dominance. Rows in *bold* refer to the most dominant species

	ST1 W95		ST2 W95		ST3 W95		ST4 W95		ST1 S95		ST2 S95		ST3 S95		ST4 S95	
	f	*D*	*f*	*D*	*f*	*D*	*f*	*D*	*f*	*D*	*f*	*D*	*f*	*D*	*f*	*D*
Amphithoe ramondi	0	0	0	0	0	0	5	8.17	0	0	0	0	0	0	0	0
Corophium acherusicum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C. acutum	**4**	**7.44**	**5**	**3.94**	**3**	**67.43**	**5**	**22.8**	**5**	**24.4**	**5**	**72.04**	**3**	**57.99**	**2**	**0.95**
C. insidiosum	0	0	0	0	0	0	4	0.39	0	0	0	0	0	0	0	0
C. sextonae	**0**	**0**	**0**	**0**	**3**	**1.62**	**1**	**0.05**	**0**	**0**	**0**	**0**	**3**	**4.96**	**0**	**0**
Corophium sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dexamine spiniventris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D. spinosa	0	0	0	0	0	0	4	0.66	0	0	0	0	0	0	2	0.63
Elasmopus rapax	**4**	**61.9**	**5**	**12.3**	**3**	**12.25**	**5**	**1.26**	**5**	**61.2**	**5**	**6.61**	**3**	**10.3**	**5**	**8.52**
Ericthonius brasiliensis	4	9.08	5	0.82	1	0.14	0	0	5	11.5	4	0.16	3	1.62	0	0
Jassa marmorata	0	0	0	0	1	0.27	0	0	0	0	0	0	0	0	0	0
Leucothoe serraticarpa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L. spinicarpa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liljeborgia dellavallei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maera inaequipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stenothoe cavimana	0	0	0	0	3	4.71	2	0.45	0	0	0	0	0	0	0	0
S. mono-culoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Perioculoides aequimanus	0	0	0	0	1	0.14	0	0	0	0	0	0	1	0.02	0	0
Cymodoce sp.	3	20.5	5	1.18	3	2.97	0	0	5	2.65	5	0.34	3	0.15	0	0
Iphinoe sp.	0	0	0	0	2	0.27	0	0	0	0	0	0	3	0.65	0	0
Leptochelia savignyi	**4**	**1.08**	**4**	**81.5**	**3**	**9.53**	**5**	**55.98**	**4**	**0.25**	**5**	**20.38**	**3**	**22.52**	**4**	**10.09**
Tanais cavolinii	0	0	3	0.26	0	0	0	0	0	0	5	0.47	0	0	0	0
T. dulongii	**0**	**0**	**0**	**0**	**0**	**0**	**5**	**10.24**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**79.81**
Paranthura nigropunc-tata	0	0	0	0	1	0.67	0	0	0	0	0	0	3	1.79	0	0
Number of individuals (*N*)	833		8,069		743		1,983		2,378		18,656		4,135		317	
Number of species	5		6		11		9		5		6		9		5	

As regards the divergence among groups, we found that group A had an average dissimilarity percentage of 75.2% with group B, 88.4% with group C, 97.8% with group D and 96.2% with group E. The species *C. acutum*, *L. savignyi*, *T. dulongi* and *A. ramondi* contributed 90% of the dissimilarity percentage between groups A and B; *T. dulongi*, *L. savignyi* and *E. rapax* between groups A and C; *L. savignyi*, *E. rapax*, *C. acutum*, *E. brasiliensis* and *T. dulongi* between groups A and D; and *C. acutum*, *L. savignyi*, *E. rapax*, *C. sextonae* and *T. dulongi* between groups A and E. Group B had an average dissimilarity percentage of 96.6% with group C, 82.2% with group D and 65.4% with group E. *C. acutum*, *L. savignyi*, *T. dulongi* and *A. ramondi* were responsible for 90% of the dissimilarity with group C; *L. savignyi*, *C. acutum*, *E. rapax*, *E. brasiliensis* and *T. dulongi* with group D; and *C. acutum*, *L. savignyi*, *E. rapax*, *C. sextonae*, *T. dulongi* and *E. brasiliensis* with group E. Group C had an average dissimilarity of 97.1% with group D and 96.3% with group E. *L. savignyi*, *E. rapax*, *C. acutum* and *E. brasiliensis* accounted for 90% of the above dissimilarity with group D; and *C. acutum*, *L. savignyi*, *E. rapax* and *C. sextonae* with group E. Finally, groups D and E showed an average dissimilarity of 68.9%. *L. savignyi*, *C. acutum*, *E. rapax*, *E. brasiliensis* and *C. sextonae* contributed 90% of this value. It is quite clear that only a few species are important in characterizing or differentiating sites.

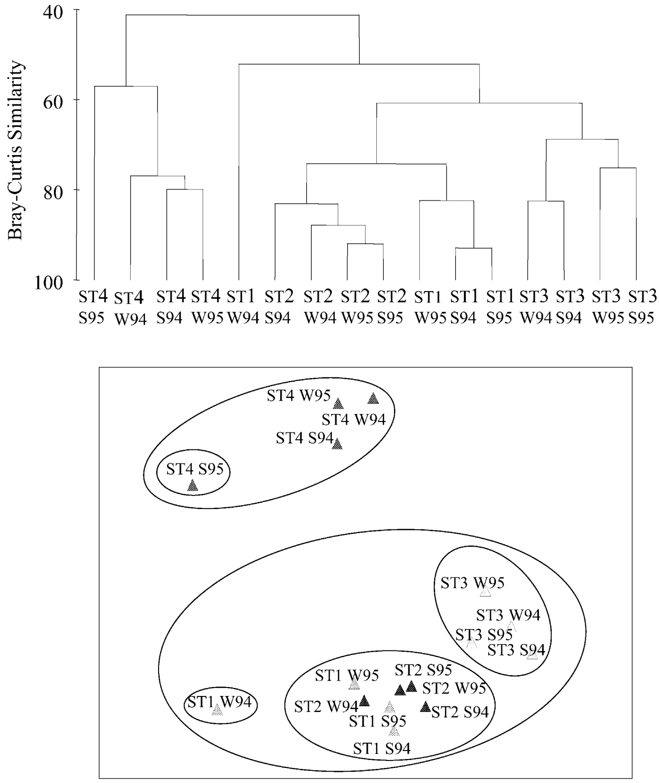

Fig. 3 Dendogram using group-average linking on Bray-Curtis and multidimensional scaling analysis from standardised species numerical abundance data of 16 samples. *W* Winter, *S* summer; *numbers* refer to year

Discussion

All the species found during this study had been reported as common fouling organisms and also as members of sublittoral hard substrate assemblages, having a wide geographical range across the Mediterranean Sea (Bellan-Santini 1969; Stephanidou and Voultsiadou-Koukoura 1995). However, some of them show ecological preferences in some Mediterranean regions which differ from those reported in the literature (e.g. Saldanha 1974; Bellan-Santini and Desrosiers 1977; Kocatas 1978; Bellan-Santini 1981; Bellan Santini et al. 1982, 1994; Hong 1983; Topaloglou and Kihara 1993; Lantzouni et al. 1998; Baxevanis and Chintiroglou 2000). For instance, the main habitats of *C. acutum* are sponges and the benthic assemblages in ports (Isaac et al. 1994). The typical representatives of the genus *Corophium* in the assemblages of photophilic algae are *Corophium volutator* and *C. acherusicum*, as reported by Kocatas (1978), Saldanha (1974) and Topaloglou and Kihara (1993). The genus *Corophium* has a wide ecological distribution (Ruffo 1998), favoured by the presence of organic particles which are used for tube-building and as food (typical filter feeders). *Ericthonius brasiliensis* was reported to live in the polluted waters of Turkish ports and in ports of Los Angeles, USA (Barnard 1958; Kocatas 1978). *Elasmopus rapax* was reported as a fouling organism (Ruffo 1998), but another species of the same genus, *E. poecillimanus*, is characteristic of clear waters (Bellan-Santini 1981; Tsuchiya and Bellan-Santini 1989). *T. cavolinii* is a detritivorous species which is very common in ports and in clear water conditions (Tsuchiya and Bellan-Santini 1989). This species was present in only five out of 16 samples. Its presence at ST4 (D=37.42) was indicative of the water conditions, whereas its presence at ST2 was very limited (D<0.01). *Leptochelia savingyi* is a species characteristic of environments rich in organic matter: it can grow fast under eutrophic conditions (Tsuchiya and Bellan-Santini 1989). This species has also often been reported as a member of assemblages of soft photophilic algae, sponges and *Posidonia oceanica* meadows (e.g. Bellan-Santini 1969; Kocatas 1978; Isaac et al. 1994). *Cymodoce* sp. was significantly present only at ST1 and ST2, a fact which is probably related to organic pollution. These facts imply that there are different species of Peracarida in different ports. Therefore, their composition as a pollution indicator must be treated separately in each case. An example for this is the port of Marseilles, where Bellan-Santini (1981) and Desrosiers et al. (1982) reported *Jassa falcata* as a pollution indicator, a species absent from the NW Aegean Sea.

We generally agree with Bellan-Santini (1981) that the ratio of certain peracarid genera can be a reliable indicator of environmental health. This presupposes, however, that

1. There is both a pollution indicator genus and a clear water indicator with a wide geographical range (or at least a local replacement of such genera by others with similar ecological demands); and that
2. Long-term data are available which allow the influence of biotic interactions to be determined.

In any case, the data must be explained with caution because the biological cycle of most of the species is not fully understood and a population outbreak of one of them would alter the results.

The feeding habits of Peracarida play a decisive role in their distribution in benthic assemblages, because the animals' migratory activities are quite limited (Barnard 1958, 1963). The dominant species at our study sites were tube-dwellers. This behaviour is usually connected with filter feeding or feeding on detritus (Isaac et al. 1994), and migration is largely restricted to reproductive purposes (Barnard 1958, 1963). The environment of semi-polluted and polluted harbours favours the dominance of such species, due to the accumulation of organic material (Tsuchiya and Bellan-Santini 1989).

The diversity values measured in the present study are similar to those reported from other Mediterranean regions (e.g. Marseilles). According to Bellan-Santini (1981) and Desrosiers et al. (1982), the H' index ranged from 2.4 to 4.6 in non-polluted, and from 0.16 to 1.96 in polluted areas. The amphipod fauna of *Mytilus galloprovincialis* assemblages in NE Thermaikos Gulf showed a diversity (H') close to 1.0 (Lantzouni et al. 1998).

Variations in diversity indices (H' and J') seem to be affiliated to various biotic and abiotic factors. For example, the numerical abundance of Peracarida had its maximum in summer (with the exception of ST4). Lantzouni et al. (1998) presented similar findings for *M. galloprovincialis* assemblages, which were attributed to the reproductive efforts of certain species. Additionally, the variability of microhabitats of certain biotopes may also increase the diversity (Tsuchiya and Nishihira 1986; Damianidis and Chintiroglou 2000).

The multivariate analysis shows a clear ranking of the stations with respect to their pollution status. ST1 and ST2 share some common features, and are both exposed to heavy pollution. This is strongly supported by Shannon (H') and Evenness (J') indices and also by the number of species (N_S). On the other hand, ST3 and even more ST4 differ from ST1 and ST2, particularly with respect to the number of species found. This is probably due to the stations' greater distance from the main sources of pollution in Thermaikos Gulf. The clustering of the samples did not reveal any pattern with respect to the period of sampling (clustering of summer and winter samples). The assemblages at all stations were dominated by a few species, resulting in low biodiversity (Dahl and Dahl 2002). An area is usually considered as heavily affected by pollution when the community shows no seasonal pattern or variations in its normal faunal composition. In such cases, some species are very abundant, a fact that indicates some kind of disturbance in the area (Gray and Mirza 1979). Methods such as ABC (abundance/biomass comparison) by Warwick (1986) or k-dominance (Clarke 1990) are not always applicable to organisms such as Peracarida whose biomass is very low (Clarke and Warwick 1994). Many authors consider crustaceans to be excellent objects for biomonitoring studies (Bellan-Santini 1981; Wenner 1988; Thomas 1993). The present study supports this opinion, as it has demonstrated that peracarid communities generally respond to water conditions, and that their composition can play an important role as a pollution indicator. However, for biomonitoring ports of different historical background and different use, methods have to be adjusted adequately for each special case, on the basis of long-term studies.

References

Barnard JL (1958) Amphipoda crustaceans as fouling organisms, in Los Angeles-Long Beach harbors, with reference to the influence of seawater turbidity. Calif Fish Game 44:161–170

Barnard JL (1963) Relationship of benthic Amphipoda to invertebrate communities of inshore sublittoral sands of Southern California. Pac Nat 3:439–467

Baxevanis A, Chintiroglou C (2000) Peracarida crustaceans of the artificial hard substratum in N Michaniona (N Aegean). Belg J Zool 130 [Suppl]:11–16

Bellan G, Pérès JM (1994) La pollution des Mers. Presses Universitaires de France

Bellan G, Desrosiers G, Willsie A (1988) Use of an annelid pollution index for monitoring a moderately polluted littoral zone. Mar Pollut Bull 19:662–665

Bellan-Santini D (1968) Contribution a l'étude des milieux portuaires (Le Vieux Port de Marseille). Rapp Comm Int Mer Mediterr 19: 93–95

Bellan-Santini D (1969) Contribution à l'étude des peuplements infralittoraux sur substrat rocheux. Trav Stat Mar Endoume Bull 31:1–294

Bellan-Santini D (1981) Influence des pollutions sur le peuplement des amphipodes dans la biocénose des algues photophiles. Tethys 10:185–194

Bellan-Santini D (1983) The Mediterranean benthos: reflections and problems raised by a classification of the benthic assemblages. In: Maraitou-Apostolopoulou M, Kiortsis V (eds) Mediterranean marine ecosystems. NATO conference series 2. Ecology vol 8 Proceedings of a NATO ARW on Mediterranean marine Ecosystems, 23–27 September, Heraclion Crete, Greece. Plenum, New York, pp 19–47

Bellan-Santini D, Desrosiers G (1976) Distribution de substrat dur dans un golfe soumis à de moultiples pollutions (golfe de Fos). 3rd Journées Étud. Pollutions, CIESM, Split, pp 153–157

Bellan-Santini D, Desrosiers G (1977) Action du rejet thermique de l'usine de Martigues-Ponteau sur les peuplements de substrats durs à dominance de zoobenthos dans la partie supérieure de l'étage infralittoral. Tethys 8:83–92

Bellan-Santini D, Karaman G, Krapp-Schickel G, Ledoyer M, Myers AA, Ruffo S, Schiecke U (1982) The Amphipoda of the Mediterranean. Part 1. Gammaridea (Acanthonotozomatidae to Gammaridae). Mem Inst Oceanogr, Monaco 13

Bellan-Santini D, Lacaze JC, Poizat C (1994) Les biocénoses marines et littorales de Méditerranée, synthése, menaces et perspectives. Mus Natl Hist Nat, Paris

Chintiroglou C, Koukouras A (1992) A population of the sea anemone *Anemonia viridis* (Forskal, 1775) and its associated flora and fauna in the North Aegean Sea. Int Rev Ges Hydrobiol 77:483–495

Clarke KR (1990) Comparison of dominance curves. J Exp Mar Biol Ecol 138:143–157

Clarke KR (1993) Non-parametric multivariate analyses of changes in community structure. Aust J Ecol 18:117–143

Clarke KR, Green RH (1988) Statistical design and analysis for a 'biological effects' study. Mar Ecol Prog Ser 46:213–226

Clarke KR, Warwick MR (1994) Change in marine communities: an approach to statistical analysis and interpretation. Natural Enviroment Research Council, UK

Daget J (1979) Les modèles mathèmatiques en écologie. Masson, Paris

Dahl L, Dahl K (2002) Temporal, spatial and substrate-dependent variations of Danish hard-bottom macrofauna. Helgol Mar Res 56:159–168

Damianidis P, Chintiroglou C (2000) Structure and function of Polychaetofauna living in *Mytilus galloprovincialis* assemblages in Thermaikos Gulf (north Aegean Sea). Oceanol Acta 23:323–339

Desrosiers G, Bellan-Santini D, Brethes JC (1982) Évolution spatio-temporelle des peuplements de substrats rocheux superficiels dans un golfe soumis à de multiples pollutions (Golfe de Fos, France). Tethys 10:245–253

Gouvis AN (1988) Qualitative and quantitative study of benthic macrofauna at Evros estuary. Thesis, Aristotle University, Thessaloniki

Gray J, Mirza F (1979) A possible method for the detection of pollution-induced disturbance on marine benthic communities. Mar Pollut Bull 10:142–146

Hargrave BT, Thiel H (1983) Assessment of pollution-induced changes in benthic community structure. Mar Pollut Bull 14:41–46

Hart BH, Fuller SLH (1979) Pollution ecology of estuarine. Academic Press, New York

Hong JS (1983) Impact of the pollution on the benthic community. Bull Korean Fish Soc 16:279–290

Isaac MJ, Makings P, Naylor E, Smaldon G, Withers RG (1994) Crustacean II: Malacostraca Peracarida. In: Hayward PJ, Rylan JS (eds) The marine fauna of the British Isles and North-West

Europe, vol 1. Introduction to Protozoans and Arthropods. Oxford Science Publications, pp 362–488
Kaandorp JA (1986) Rocky substrate communities of the infralittoral fringe of the Boulonnais coast, NW France: a quantitative survey. Mar Biol 92:255–265
Kamba E, Artemiadou V, Lazaridou-Dimitriadou M (2000) Ecological quality of the river Axios (N Greece) during spring and summer 1997. Belg J Zool 130(suppl.):23–30
Kluijver MJ, Leewis RJ (1994) Changes in sublittoral hard substrate communities in the Oosterschelde estuary (SW Netherlands), caused by changes in the environmental parameters. Hydrobiologia 282/283:265–280
Kocatas A (1978) Contribution à l'étude des peuplements des horizons supérieurs de substrat rocheux du Golfe D'Izmir (Turquie). Ege Univ Fen Fak Monogr Ser 12:1–93
Lantzouni M, Voultsiadou E, Chintiroglou C (1998) Preliminary observations on amphipod assemblages associated with *Mytilus galloprovincialis* Lam. beds from Thermaikos Gulf (Aegean Sea). Rapp Comm Int Mer Medit 35:458–459
Leewis RJ, Waardenburg HW (1989) The flora nad fauna of the sublittoral part of the artificial rocky shores in the south-west Netherlands. Prog Underw Sci 14:109–122
Meijering MPD (1991) Lack of oxygen and low pH as limiting factor for Can. Hessian brooks and rivers. Hydrobiologia 223:159–161
Nikolaidis G, Moustaka-Gouni M (1990) The structure and dynamics of phytoplankton assemblages from the inner part of the Thermaikos Gulf, Greece. I. Phytoplankton composition and biomass from May 1988 to April 1989. Helgol Meeresunters 44:487–501
Pérès JM, Picard J (1964) Nouveau manuel de bionomie benthique de la Méditerranée. Rec Trav Stat Mar Endoume 31:1–137
Reish DR, Barnard JL (1979) Amphipods (Arthropoda:Crustacea:Amphipoda). In: Hart CW, Fuller SLH (eds) Pollution ecology of estuarine. Academic Press, New York, pp 345–370
Ruffo S (1998) The Amphipoda of the Mediterranean. Mem Inst Oceanogr Monaco 13:814–959
Saldanha L (1974) Estudo do povoamento dos horizontes superiores da rocha litoral da costa da Arrabida (Portugal). Publ Mus Lab Zool Anthropol Fac Cien Lisboa 5:1–382
Samanidou V, Fytianos K, Vasilikiotis G (1987) Distribution of nutrients in the Thermaikos Gulf, Greece. Sci Total Environ 65:181–189
Stephanidou D, Voultsiadou-Koukoura E (1995) An account of our knowledge of amphipod fauna of the Aegean sea. Crustaceana 68:597–615
Stergiou KI, Christou ED, Georgopoulos D, Zenetos A, Souvermezoglou C (1997) The Hellenic Seas: physics, chemistry, biology and fisheries. Oceanogr Mar Biol Annu Rev 35:415–538
Stirn J (1981) Manual of methods in aquatic environment research. Part 8. Ecological assessment of pollution effects (Guidelines for the FAO GFCM/UNEP Joint Coordinated Project on Pollution in Mediterranean). FAO Fish Tech Pap 209:1–190
Taramelli-Rivosecchi E (1969) Ricerche sulle zoocenosi delle alge fotofile e in particolare di *Halopteris scoparia* (L.) Pubbl Stn Zool Napoli 37:349–358
Thomas JD (1993) Biological monitoring and tropical biodiversity: a critique with recommendations and comments on the use of amphipods as bioindicators. J Nat Hist 27:795–806
Topaloglou B, Kihara K (1993) Community of Mediterranean mussel *Mytilus galloprovincialis* Lamark, 1819 in the Bosphorus strait. J Tokyo Univ Fish 80:113–120
Tsuchiya M, Bellan-Santini D (1989) Vertical distribution of shallow rocky shore organisms and community structure of mussel beds (*Mytilus galloprovincialis*) along the coast of Marseille, France. Mésogée 49:91–110
Tsuchiya M, Nishihira M (1986) Islands of *Mytilus edulis* as a habitat for small intertidal animals: effect of *Mytilus* age structure on the species composition of the associated fauna and community organization. Mar Ecol Prog Ser 31:171–178
Tursi A, Matarrese A, Sciscioli M, Vaccarella R, Chieppa G (1982) Biomasse benthoniche nel Mar Piccolo di Taranto e loro rapporto con ibanchi naturali di mitili. Nat Sicil 2[Suppl]2:263–268
Tursi A, Matarrese A, Matarrese A, Scalera Liaci L, Montanaro C, Cecere E (1984) Seasonal factors in mussel facies settlement on annual fouling panels. Oebalia 10:69–84
Warwick RM (1986) A new method for detecting pollution effects on marine macrobenthic communities. Mar Biol 92:557–562
Weinberg S (1978) The minimal area problem in invertebrate communities of Mediterranean rocky substrate. Mar Biol 49:33–40
Wenner AM (1988) Crustacean and other invertebrates as indicators of beach pollution. In: Soule DF, Kleppel GS (eds) Marine organisms as indicators. Springer, Berlin Heidelberg New York, pp 199–229
Zavodnik D, Zavodnik N (1978) The benthos of Rijeka Bay—subject to stress and pollution. IVes Journées Étud. Pollutions. CIESM, Antalya, pp 405–410