CRUSTACEANS DISTRIBUTION PATTERN ON VERTICAL CLIFFS IN THE NORTH AEGEAN (EASTERN MEDITERRANEAN)

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SUMMARY

The spatial dispersion of crustaceans as part of the sciaphilic algae community in the northern part of the Aegean Sea was studied. The examination of the collected 1,611 specimens revealed the presence of 60 species. Multivariate analyses showed high similarity between sites, however, four distinct assemblages were recorded in accordance with depth, the habitat complexity defined by the occurrence of different algal forms, the degree of hard substrates' inclination and the water clarity.

KEYWORDS:
biodiversity, crustacean, hard substrate, infralittoral, Aegean Sea.

INTRODUCTION

Crustacea is a highly biodiverse group, both numerically and functionally in marine ecosystems [1]. As regards the hard substratum communities in the Mediterranean, crustaceans are among the prominent biota, together with polychaeta and mollusca, in terms of species richness and abundance [2-5]. Given their ecological weight, there are many references suggesting their importance as sensitive environmental indicators [2, 6-10]. However, very few studies deal with biodiversity patterns of the crustacea, as information derives only from the photophilic algae community and the port assemblages in the upper layer of the infralittoral zone [2, 5, 10-13], whereas relevant data from the lower layer are missing [14, 15]. The study of the biodiversity in the Mediterranean has been intensified in recent years, since its value as an indicator of environmental quality and function of ecosystems has been recognized [16-18]. However, we are still far from understanding the marine biodiversity, mainly due to paucity of relevant data [1, 19].

This study took place at the lower layer of the infralittoral zone (below 15 m), where the sciaphilic algae community normally occurs on inclined hard substrate [14, 20, 21]. The basic aim was to detect crustaceans' pattern of dispersion along a vertical cliff and the most critical factors that influence its distributional range.

MATERIALS AND METHODS

Study area

The study area is located along the coastline of Chalkidiki peninsula and the bay of Kavala, in the northern part of the Aegean Sea, where seven coastal stations were selected (Figure 1). All sites share some common physical characteristics, such as hard substrate down to 30-40 m depth and inclination bigger than 50° [15]. At each site, one to three depth levels were set (15, 30 and 40 m) for the bathymetrical study of the lower infralittoral zone.

Sampling techniques

At each site and depth level, sampling was carried out by SCUBA diving using a 400- cm^2 quadrate sampler [22], by totally scraping off the substrate [23, 24]. Five replicates were collected during summer of 1997 and 1998. Overall, 75 samples were obtained. All samples were sieved (0.5 mm) and preserved in 10% formalin. After the sorting process, the specimens of crustacea were identified at species level and counted. Algae were also identified and the dominant species were recorded. Concurrently, the main abiotic factors, e.g. temperature, salinity, conductivity, dissolved O_2 and pH, were measured in the water column. Water clarity was measured with the Secchi disc, while the inclination of hard substratum was calculated with a clinometer.

Data analysis

Data was first analyzed by common biocoenotic methods [23, 13]. Thus, the numerical abundance on a scale of $1m^2$ (A/m^2), the mean dominance (mD), the frequency (F) and diversity indices (Margalef's richness, Shannon-Wiener and Pielou's evenness, based on $\log_2$) were calculated.

In order to check the null hypothesis that the abundance of crustaceans does not differ significantly between sites and depth levels, a mANOVA test (2-way) was carried out. A logarithmic transformation (logx+1) was used to normalize the variance of numerical abundances [25, 26].

The data obtained per sampling site were analyzed by multidimensional scaling techniques, based on the Bray-Curtis similarity and root transformed numerical abun-

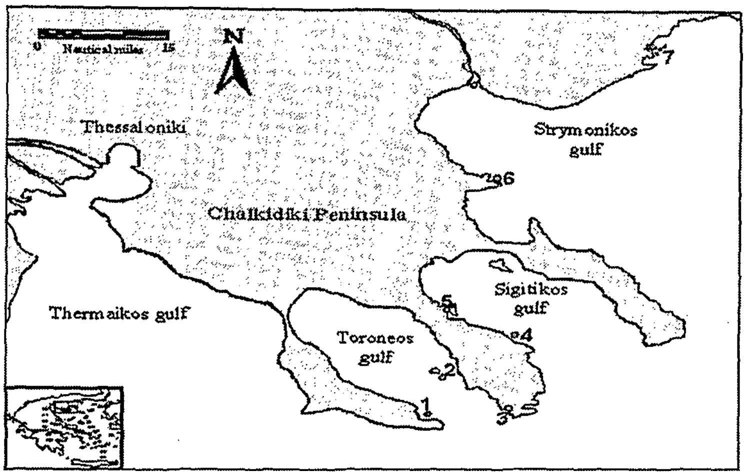

FIGURE 1 - Map of the study area indicating sampling sites.

dances, using PRIMER package [27]. The significance of the multivariate results was assessed with ANOSIM test. SIMPER analysis was applied to identify the contribution of each species to the overall similarity within a site and the dissimilarity among sites [27]. Finally, the BIOENV procedure was used to examine which environmental parameters are related to the observed biotic pattern (MDS plot) and the degree of this relation [27].

RESULTS

Community structure

According to the morphology of the dominant phytobenthic species, in terms of percent coverage, e.g. the 'pilot species' [23] at each site, four distinct assemblages were recorded: (1) fan-shaped and filamentous forms, traced at sites 1, 2, 3 and 4, (2) bush-like and filamentous forms at site 7, (3) encrusting forms at sites 1 and 3 at the depth of 40 m, and (4) encrusting and filamentous forms at site 5 [15].

TABLE 1 - Taxonomic list of the recorded Crustaceans.

Achaeus cranchii Leach, 1817	*Leptocheirus pectinatus* (Norman, 1869)
Alpheus dentipes Guérin-Méneville, 1832	**Leptochelia savignyi* (Kroyer, 1842)
Ampelisca scarsi Cheuvreux, 1888	*Leucothoe spinicarpa* (Abildgaard, 1789)
Amphithoe ramondii Audouin, 1826	*Liljeborgia psaltrica* Krapp-Schickel, 1975
Aora spinicornis Afonso, 1976	**Lysianassa caesarea* Ruffo, 1978
**Apseudes intermedius* (Milne-Edwards, 1828)	**Lysianassa costae* (Milne-Edwards, 1830)
Athanas nitescens (Leach, 1814)	*Lysianassa longicornis* (Lucas, 1849)
Balanus a. amphitrite Darwin, 1854	*Lysianassa plumosa* Boeck, 1871
**Caprella acanthifera* Leach, 1814	*Lysmata seticaudata* (Risso, 1816)
**Caprella rapax* Mayer, 1890	*Macropodia* sp.
Cestopagurus timidus (Roux, 1830)	*Metaphoxus simplex* (Bate, 1857)
Chelonibia sp.	**Microdeutopus anomalus* (Rathke, 1843)
Colomastix pusilla Grube, 1861	*Orchomene humilis* (Costa, 1853)
**Corophium acherusicum* Costa, 1851	*Paguristes eremita* (Linnaeus, 1767)
Corophium acutum Cheuvreux, 1908	*Pagurus anachoretus* Risso, 1827
**Corophium insidiosum* Crawford, 1937	*Pagurus* sp.
**Cumella limicola* G.O. Sars, 1879	*Paradoxostoma* sp.
Cymodoce truncata (Montagu, 1804)	**Paranthura nigropunctata* (Lucas, 1849)
Dexamine spiniventris (Costa, 1853)	*Perioculodes longimanus* (Bate & Westwood, 1868)
**Dexamine spinosa* (Montagu, 1813)	**Phtisica marina* Slabber, 1749
Ebalia deshayesi Lucas, 1846	*Pilumnus spinifer* H. Milne-Edwards, 1834
Eualus occultus (Lebour, 1936)	*Pisa armata* (Latreille, 1803)
Eurydice truncata (Norman, 1868)	*Pisa mucosa* (Linnaeus, 1758)
Eusirus longipes Boeck, 1861	*Pseudocuma longicornis* (Bate, 1858)
Gallathea intermedia Lilljeboorg, 1851	**Stenothoe monoculoides* (Montagu, 1815)
**Gnathia vorax* (Lucas, 1849)	*Synchelidium longidigitatum* Ruffo, 1947
Gnathia sp. praniza	**Tanais dulongii* (Audouin, 1826)
**Hyale camptonyx* (Heller, 1866)	*Thoralus cranchii* (Leach, 1817)
**Idotea baltica basteri* Audouin, 1827	*Urothoe elegans* (Bate, 1857)
Iphinoe sp.	*Verruca spengleri* Darwin, 1854

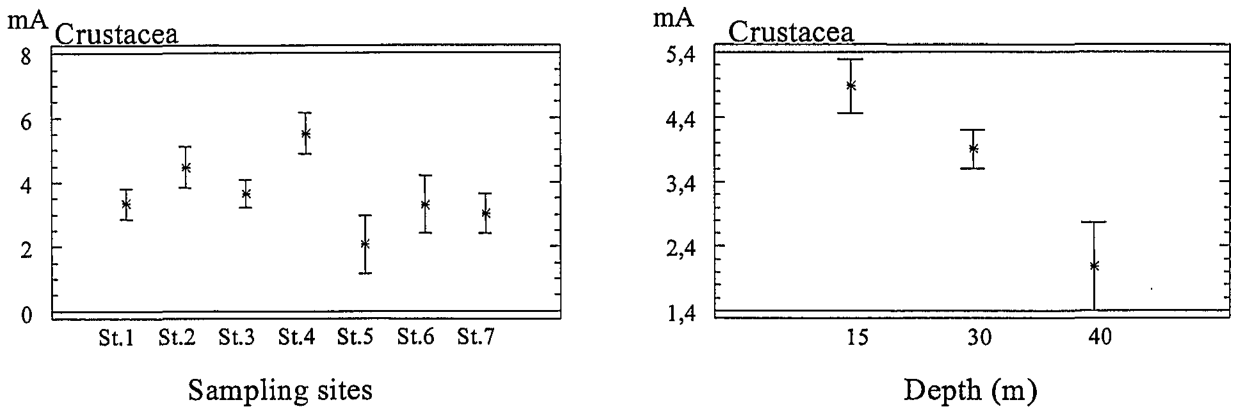

FIGURE 2 - Mean abundance (mA) of Crustacea (left: sampling sites, right: depth level). Bar code = standard deviation.

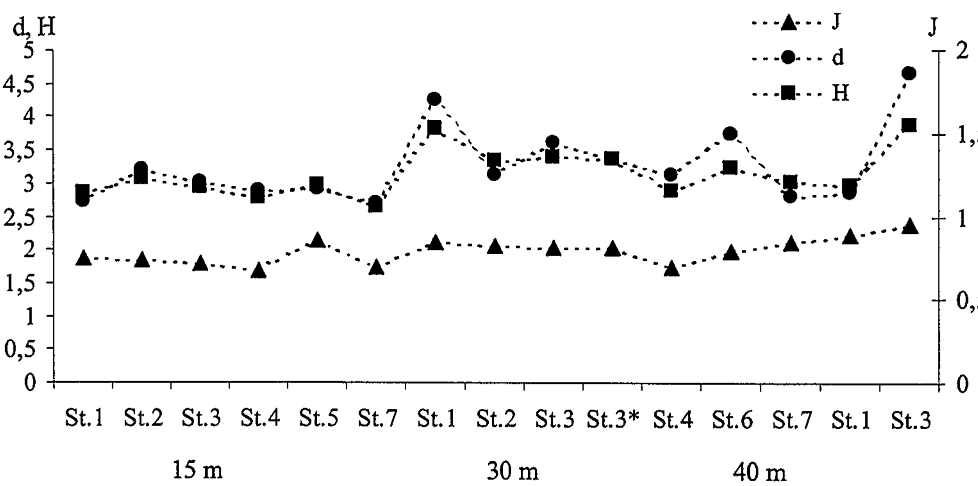

FIGURE 3 - Diversity indices per depth level (15, 30 & 40 m) and site (d = Margalef's richness, H' = Shannon-Wiener index, J' = Pielou's evenness).

A total of 1,611 individuals were counted, belonging to 60 species of: Cirripedia (3 species), Ostracoda (1 species), Amphipoda (28 species), Anisopoda (3 species), Isopoda (6 species), Cumacea (3 species), Decapoda (17 species). 18 species were dominant (Table 1), according to population density and frequency values (over 60%). From these species only *Dexamine spinosa* dominate at all sites.

The dispersion of Crustacea was not equal among the seven sampling sites or the three depth levels (ANOVA results: F=5.43, p=0.00; F=13.69, p=0.00 respectively). The partial differences for each factor are depicted in Figure 2.

The values of diversity indices were high, except of richness values (d) that ranged from 2.71 to 4.66 (Figure 3), indicating the relatively low number of species per sampling site. However, the numerical abundance was quite evenly dispersed among species (H values ranged from 2.79 to 3.89 and J' values from 0.72 to 0.95), as only at the depth level of 15 m (at all sites but St.5) the occurrence of a specific species was observed.

Affinity of sites and depth levels

Non-metric MDS indicates the separation of the sites and depth levels in three main groups, while St.5 discriminates alone (Figure 4). Inside group A, a second minor grouping according to depth is apparent. The main discrimination of the three groups is confirmed by one-way ANOSIM (global R = 0.94 p < 0.1). The pair-wise test showed significant differences among all group combinations (R ranging from 0.89 to 1). The SIMPER analysis identified 10 species as most contributing to in-group similarity and 22 species to among-groups dissimilarity (Table 2).

The BIOENV procedure showed that the substrate inclination and the water clarity are the factors that relate mostly with the community structure (Spearman rank correlation 0.53).

DISCUSSION

The basic concept of biodiversity focuses on species richness, e.g. composition that is the important indicator of diversity across spatial scales and habitats [16, 17]. As regards the biodiversity of Crustacea on hard substrate macrozoobenthic communities, a total of 196 species were quantitatively collected from the Aegean coasts, according to literature review (Table 3). Thus, it came up that two facies of the photophilic algae community, i.e. the brown alga *Padina pavonica* and the mussel *Mytilus galloprovincialis*, host the greater number of crustacean species, followed by one facies of the sciaphilic algae community, i.e. the filamentous red algae. The lower biodiversity was recorded on port assemblages together with the facies of the green alga *Ulva rigida*, both developed under the influence of organic pollution [11, 13, 23].

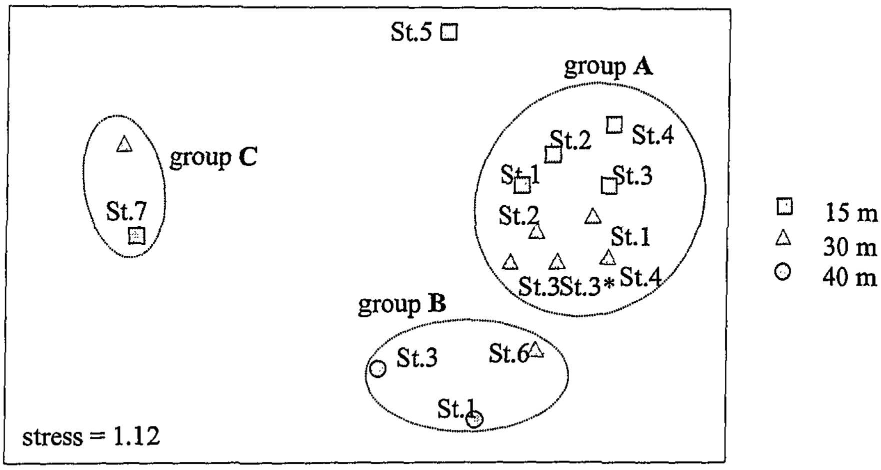

FIGURE 4 - Non-metric multidimensional scaling, based on Bray-Curtis similarity index, calculated from root transformed numerical abundance data.

TABLE 2 - Species contributing to about 60% of the average in-group similarity or the average among groups dissimilarity.

	Average similarity			Average dissimilarity					
	A 57.16	B 48.17	C 50.88	A-B 59.27	A-C 58.89	B-C 68.84	A-D 75.48	B-D 72.71	C-D 69.99
Alpheus dentipes				3.17	3.43				
Aora spinicornis	13.52			8.42		10.05	4.61	4.24	6.00
Apseudes intermedius	14.26	16.90		4.90	9.02	5.13	6.97	5.31	
Balanus amphitrite	15.26			10.18	9.07	4.64	8.80		6.78
Caprella acanthifera				3.42	4.18		2.91		
Colomastix pusilla							3.27	3.76	4.75
Corophium acutum			21.99				6.72	9.85	11.23
Cumella limicola					3.21				
Cymodoce truncata						4.00	3.70	3.64	7.08
Dexamine spiniventris	17.11	20.01		3.96	8.02	5.17	5.42	4.02	
Eualus occultus							2.65		
Eurydice truncata		10.27		4.81	7.49	5.13	4.49		
Gnathia vorax				3.36	3.02			3.72	
Leptochelia savignyi				3.17		4.92		3.72	
Leucothoe spinicarpa				2.81	2.78				
Liljeborgia psaltrica	8.97			4.95	3.14	4.89	4.41	5.74	
Lysianassa caesarea			22.91				7.82	11.32	13.71
Orchomene humilis		17.67		2.96				5.26	
Paranthura nigropunctata				4.05	3.23	3.51			
Pycnogonum littorale			15.37					6.42	
Tanais dulongii					5.73	9.07			3.90
Urothoe elegans						5.56			5.30

TABLE 3 - Species richness of the Crustaceans communities in the Aegean.

Reference	[11]	[11]	[11]	[11]	[11, 10]	[11, 5]	[22,*]	*	**	**	**
Community	Photophilic Algae								Sciaphilic Algae		
Facies	C	Cy	Pa	U	P	Mg	A	PA	FF	E	BF
Species richness	44	53	69	39	21	62	36	35	60	33	26

C = Corallina facies, Cy = Cystoseira facies, Pa = Padina facies, U = Ulva facies, P = Port assemblages, Mg = Mytilus facies, A = Anemonia facies, PA = Photophilic algae facies, FF = Filamentous, fan-shaped algal facies, E = Encrusting algal facies, BF = Bush-like, filamentous algal facies, * Chintiroglou, unpublished data, ** Present study

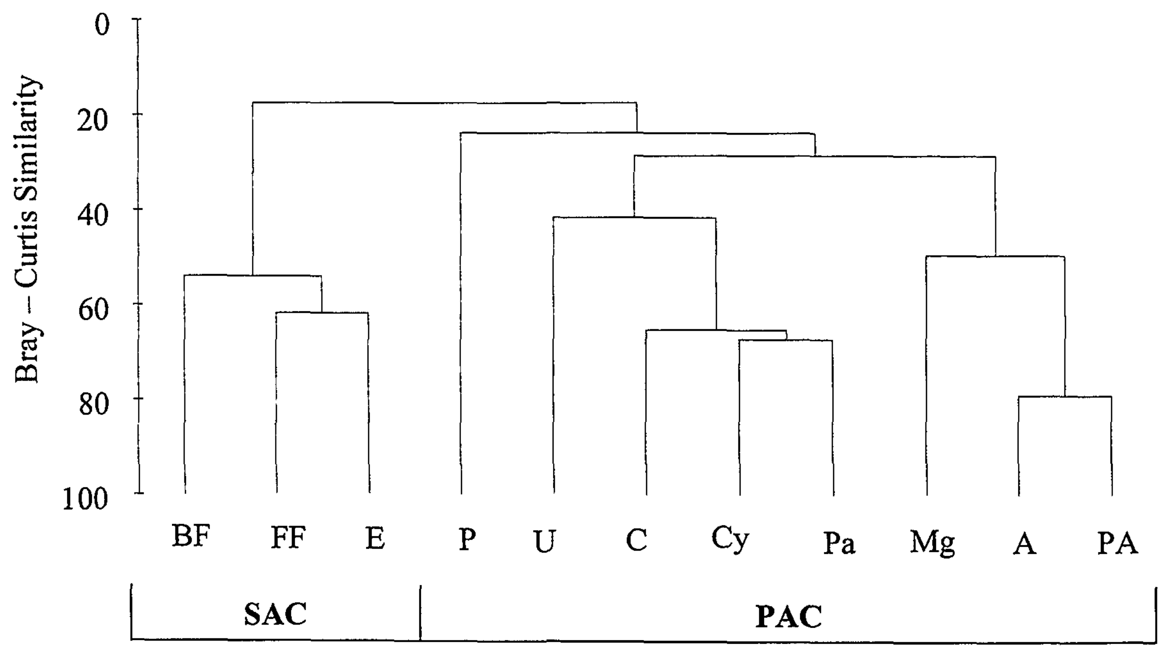

FIGURE 5 - Hierarchical cluster analysis, based on Bray-Curtis similarity index, calculated from presence / absence data (For abbreviations see Table 3).

Comparing the similarity of crustacean fauna in the Aegean hard substrate communities (Fig. 5), a clear separation of the photophilic (PAC) and the sciaphilic (SAC) communities is evident. In the PAC cluster, the higher similarities occur among the facies of the genus *Cystoseira*, *Corallina* and *Padina*, which develop in clear waters [11, 23]. The facies of the mussel shows increasing similarity to those of the common sea anemone and the algae *Codium fragile*, *Spyridia filamentosa*, *Gigartina teedii*, *Gelidium pusillum* and *Dictyota spiralis*, which are under the loose influence of organically rich material [10, 28, 29]. The growth of mussel beds leads to accumulation of organic load [3, 5], thus favors the settlement of species related to eutrophic conditions [2, 10]. Finally, the port assemblages discriminate as they host fairly low number of crustacean species, all tolerant to organic pollution [2, 4, 6, 10]. Besides, the response of crustacea on various levels of pollution has been well documented [2, 6-8, 10, 12]. As regards the SAC cluster, the three facies studied, show increase similarity *inter se*, despite the different species richness recorded (Table 3).

All the recorded species in this study were previously reported in the Aegean Sea [30, 31]. However, there is another aspect in the study of their ecological preferences added here, namely, their distributional pattern along a vertical cliff. As the results of the quantitative analyses showed, the affinity of the four stations located at Chalikidiki peninsula is high (St.1, St.2, St.3, St.4). This was expected, since these four stations share some common characteristics, as the highly incline rocky substrate (60-90°), the great depth and the similar abiotic factors. However, St.5 -also located in Chalkidiki peninsula- discriminates as it hosts a low number of crustacean species and individuals. The lowest value in water clarity was also recorded at this station, where the inclination was slight (55°) and the substrate is of purely organic material (dead colonies of the scleractinian *Cladocora caespitosa*).

St.6 was placed with the 40 m depth level group; the main environmental factor is the reduced water clarity, due to inflows of Strymonas River [19]. Finally, St.7 discriminates mostly due to low salinity. This is the most remote station, with particular hydrological features [19].

Many authors suggest that zoobenthos is commonly related to algal zonation and it is generally affected by the presence of different algal forms [32-35, 15]. This seems to be valid also for the distribution of crustacea, as the recorded pattern corresponds well to the different algal facies. Most of the dominant algal species are sciaphilous, with the exception of the photophilous *Padina padina* [36]. The bathymetric distribution of these species is mainly determined by light, which is the result of two key factors: substrate inclination and water clarity. Besides, the BIOENV analysis identified these two factors as the most related with the biotic pattern.

As SIMPER analysis showed, there is a large number of species that contributes to both similarities within groups and dissimilarities between groups. This indicates a diverse community with a highly complex structure [37]. This heterogeneity may be conditioned by the presence of several algal species with different architecture [32, 34, 35, 38]. Thus, the fan-shaped and filamentous forms are characterized by higher diversity and abundance, followed by bush like forms. These algal forms seem to provide refuge, food and living space for several small crustaceans [33]. Besides, a large amount of sediment is entrapped among the entangled axes of the thallus increasing the complexity of the system, by offering microhabitats suitable for the settlement of many soft sediment species [34, 39].

Lastly, the encrusting algal forms are very distinctive as they occur mainly on vertical substrate at the deeper parts of the infralittoral zone [36]. Their main feature is the bio-construction of substratum through the biosynthetic process of various calcareous algal (i.e. the genus *Peyssonnelia*, *Lithothamnion*, *Lithophyllum*, *Pseudolithophyllum*, etc.), that solidifies loose sediments. These forms create one-dimensional habitats with low complexity, which is reflected on the recorded impoverished fauna [15].

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