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## Polychaetes associated with the sciaphilic alga community in the northern Aegean Sea: spatial and temporal variability

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**Abstract** Polychaete biodiversity has received little attention despite its importance in biomonitoring. This study describes polychaete diversity, and its spatial and temporal variability in infralittoral, hard substrate assemblages. Seven stations were chosen in the central area of the northern Aegean Sea. At each station, one to three depth levels were set (15, 30 and 40 m). Five replicates were collected by scuba diving with a quadrat sampler (400 cm<sup>2</sup>) from each station and depth level during summer for the spatial analysis, and seasonally for the study of temporal changes. Common biocoenotic methods were employed (estimation of numerical abundance, mean dominance, frequency, Margalef's richness, Shannon-Weaver index and Pielou's evenness). A total of 5,494 individuals, belonging to 79 species, were counted and classified. Diversity indices were always high. Clustering and multidimensional scaling techniques indicated a high heterogeneity of the stations, although these were all characterized by the sciaphilic alga community. A clear seasonal pattern was not detectable. Summer and autumn samples discriminate, while winter and spring form an even group. The abundance/biomass comparison indicated a dominance of k-strategy patterns, characteristic of stable communities.

**Keywords** Polychaeta · Infralittoral · Aegean Sea · Hard substrate · Biodiversity

### Introduction

There is a growing interest in biodiversity, defined as the collection of genomes, species and ecosystems occurring in a geographical region (CBDMS 1995). The most fundamental meaning of this term is expressed at species level by the concept of species richness (Bianchi and Morri 2000). Species richness does not simply refer to the number of species, but includes species variety, i.e. composition, which is an important indicator of diversity across spatial scales (Costello 1998). According to the Convention of Biological Diversity definition, biodiversity concerns variability within species (individual/population level), between species (community level), and at the ecosystem level (functional level). The value of biodiversity as an indicator of environment health, and for the functioning of ecosystems, is now largely recognized (Gaston and Spicer 1996; Bianchi and Morri 2000).

Polychaetes are among the most frequent and species-rich taxa in marine benthic environments (Fauchald and Jumars 1979; Costello et al. 1996). Many authors have suggested a key role of polychaetes in biomonitoring studies (Reish 1978; Bellan 1980; Wenner 1988; Warwick 1986, 1993; Damianidis and Chintiroglou 2000). Before data from polychaete assemblages can be used to identify disturbances, as demanded by international directives and conventions, it is necessary to provide a database on the composition of natural assemblages (Pocklington and Wells 1992; Gaston and Spicer 1996; Ergen and Cinar 1997).

The distribution of polychaetes in hard-bottomed sites is commonly related to algal structure and zonation (Giangrande 1988; Somaschini 1988; Sardà 1991). However, the distribution of polychaetes depends on algal cover and epiphytes more than on the presence of particular macroalgal species (Abbiati et al. 1987; Sardà 1987; Giangrande 1988; Frascchetti et al. 2002). There is a large amount of literature on polychaetes in midlittoral and infralittoral zones of the western Mediterranean (Retiere and Richoux 1973; Cardell and Gili 1988; reviewed by Sardà 1991), yet much less information on the

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Fig. 1 Map of the study area

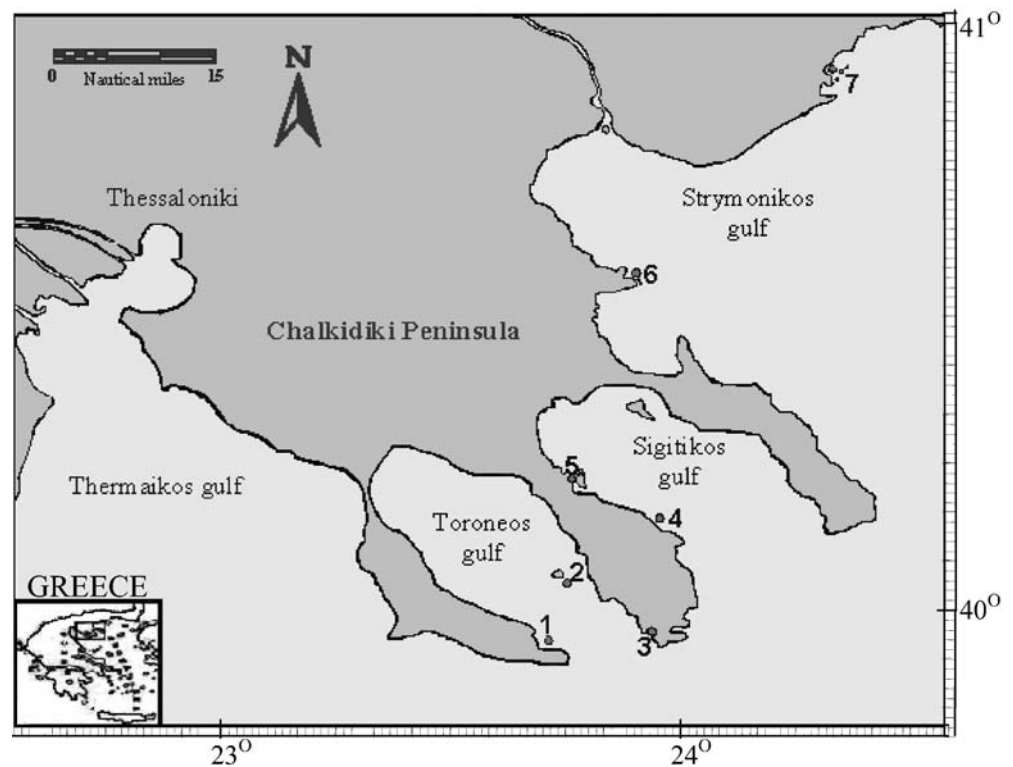


Table 1 Physical and biotic characteristics of the sampling sites

Station	Slope (°)	Maximum depth (m)	Prevailing winds	Depth level (m)	Pilot algal species
1 Kakia Skala	90	65	N, NE, SE	15 30 40	<i>Polysiphonia</i> sp. <i>Polysiphonia</i> sp., <i>Lithophyllum</i> sp. <i>Lithophyllum</i> sp., <i>Peyssonnelia</i> sp.
2 Kelyfos	70	35	S, SW, SE, NW	15 30 40	<i>Padina pavonica</i> , <i>Polysiphonia</i> sp. <i>Womersleyella setacea</i> , <i>Padina pavonica</i>
3 Porto Koufo	90	50	SW	15 30 40	<i>Womersleyella setacea</i> <i>Womersleyella setacea</i> <i>Lithophyllum</i> sp., <i>Peyssonnelia</i> sp.
4 Armenistis	50–60	35	NE	15 30	<i>Womersleyella setacea</i> , <i>Padina pavonica</i> <i>Womersleyella setacea</i>
5 Vourvourou	55	18	N, SE	15	<i>Pseudolithophyllum expansum</i> , <i>Gelidium pectinatum</i>
6 Eleftheronissos	70	30	NE, SE, N, S	30	<i>Lithothamnion</i> sp., <i>Polysiphonia</i> sp.
7 N. Iraklitsa	65	35	NE, NW, SE	15 30	<i>Cutleria multifida</i> , <i>Gelidium pectinatum</i> <i>Cutleria multifida</i> , <i>Gelidium pectinatum</i>

situation in the eastern Mediterranean (Nicolaidou et al. 1986; Bellan-Santini et al. 1994; Chintiroglou 1996; Ergen and Cinar 1997; Damianidis and Chintiroglou 2000).

According to Marinopoulos (1988), the infralittoral zone can be divided into three ecologically different belts. This study was restricted to the lowest belt (below 15 m), where the sciaphilic alga community occurs (Laubier 1966; Margalef 1984; Antoniadou et al. 2004). Its aim was to reveal the spatial and temporal variability of the polychaete fauna associated with the sciaphilic alga community.

## Methods

### Sampling sites

Seven coastal stations were selected in the northern part of the Aegean Sea (Fig. 1). These sites share some common physical characteristics, such as hard substrate down to a depth of 30–40 m and an inclination of more than 50° (for details see Antoniadou et al. 2004), which lead to the establishment of the sciaphilic alga community in the lower infralittoral zone (15–40 m). According to the vertical extension of the hard substrate, one to three depth levels (15, 30 and 40 m) were set at each station, covering the depth range of the local sciaphilic alga community. The main physical characteristics of the sampling sites are given in Table 1. For the spatial analysis, the sites were sampled during summer 1998 (stations 1–6) or summer 1999 (station 7). Station 3 was chosen for the temporal analysis (summer 1997 to summer 1998) due to its geomorphology

protecting it from the N, NE and NW winds that usually occur in this area during winter.

#### Physico-chemical factors

Measurements of the main abiotic factors (temperature, salinity, conductivity, dissolved O<sub>2</sub> and pH) were carried out along the water column using a WTW salinity-conductivity-O<sub>2</sub> meter and Lovibond Checkit (pH meter) micro-electronic equipment. Water clarity was determined using a Secchi disc. The inclination of the hard substratum was calculated using a clinometer; currents (speed and direction) were recorded using the autographic current meter Sensordata SD-4 in May 2000.

#### Data collection

Sampling was carried out by scuba diving using a quadrat sampler (Bellan-Santini 1969) covering a surface of 400 cm<sup>2</sup> (Weinberg 1978; Karalis et al. 2003). Following Marinopoulos (1988), five replicates were collected at each depth level and site (see Table 1). A total of 75 and 65 samples were available for the study of spatial and seasonal variations, respectively. All samples were sieved (0.5 mm mesh size) and preserved in a 10% formalin solution. After sorting, all polychaetes were counted, weighted (wet weight) and identified to species level. Furthermore, the algae collected were identified, and the dominant species (in terms of percentage cover) were estimated.

#### Statistics

Common biocoenotic methods were employed to analyze the data (Hong 1982; Marinopoulos 1988; Antoniadou et al. 2004). Thus, the numerical abundance per square meter (A/m<sup>2</sup>), the mean dominance (mD), the frequency (F), and a variety of diversity indices (Margalef's richness, Shannon-Weaver *H'* and Pielou's evenness *J'* based on log<sub>2</sub>) were calculated.

In order to check the null hypothesis (no significant variations in polychaete abundance), a two-way mANOVA test was used to examine the effects of two different factors: depth, and space or time. A logarithmic transformation (log<sub>x</sub>+1) was used in order to normalize the variance of numerical abundance data in both cases (Zar 1984; Clarke and Green 1988).

The data obtained from each sampling site were analyzed using cluster and multidimensional scaling (MDS) techniques, based on the Bray-Curtis similarity and log-transformed numerical abundances, using the PRIMER package (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 among sites (Clarke and Warwick 1994). Moreover, an abundance-biomass comparison (ABC curves) was performed for each site in order to detect any

kind of disturbance in the examined assemblages (Warwick 1986). All the above techniques were employed in both the spatial and temporal analysis.

## Results

### Spatial variation

#### Abiotic factors

The main abiotic parameters showed slight variations in relation to depth and sampling site (Table 2). A detailed analysis is given by Antoniadou et al. (2004). Water currents follow the general pattern of cyclonic circulation in the northern Aegean Sea (Stergiou et al. 1997; Somarakis et al. 2002).

#### Community description

All sites can be classified to the sciaphilic alga community (Augier 1982; Pérès and Picard 1964; Bellan-Santini et al. 1994). However, according to the dominant algae, four facies could be distinguished:

1. A facies of the red alga *Polysiphonia* sp. or *Womersleyella setacea*;
2. A facies of the red alga *Gelidium pectinatum* and the brown alga *Cutleria multifida*;
3. A facies of the red algae *Lithophyllum* sp., *Lithothamnion* sp. and *Peyssonnelia* sp.; and
4. A facies with the mixed occurrence of the red algae *Pseudolithophyllum expansum*, *Gelidium pectinatum*, *Lithophyllum* sp. and *Polysiphonia* sp. (see Antoniadou et al. 2004).

The main biocoenotic parameters are presented in Table 3. Overall, 4,361 individuals were counted, belonging to 79 species. Twenty-four species were the most dominant: only *Syllis hyalina* and *Nereis rava* were present at all sites.

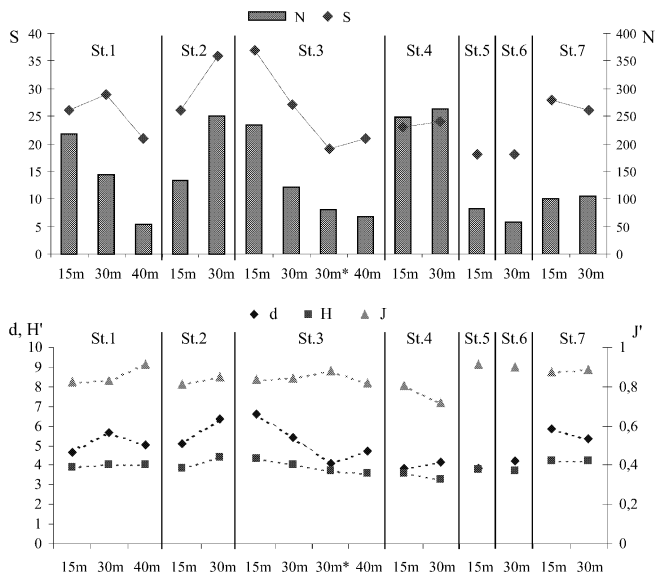
**Table 2** Mean values of the main abiotic factors in the water column (0–40 m) for stations 1–7 (summer) and for seasons (station 3). *T* temperature, *S* salinity, *C* conductivity, *WC* water clarity, *CV* water current velocity, *CD* water current direction

Station	T (°C)	S (psu)	C (μS/cm)	O <sub>2</sub> (mg/l)	pH	WC (m)	CV (cm/s)	CD
1	23.1	35.4	48.2	6.98	8.6	21	2.69	NE
2	23.1	35.3	48.1	7.42	8.2	22	1.93	N
3	21.6	36.1	49.0	7.22	8.2	20	1.80	SW
4	26.2	34.6	47.0	8.18	7.5	20	3.10	E
5	25.9	34.9	47.3	7.64	8.2	12	2.74	SE
6	23.1	34.8	47.5	7.73	8.1	21	11.40	N
7	25.7	33.2	45.5	7.75	8.7	18	1.58	NW
Seasons								
Summer	21.6	36.1	49.0	7.22	8.2	20		
Autumn	19.3	36.8	50.2	6.72	8.2	23		
Winter	12.9	37.4	51.3	6.84	8.2	18		
Spring	14.1	36.9	50.8	8.25	8.2	16		



Table 3 (continued)

Species	Station 1			Station 2			Station 4			Station 5			Station 6			Station 7		
	A			F			A			F			A			F		
	15 m	30 m	40 m	15 m	30 m	40 m	15 m	30 m	40 m	15 m	30 m	40 m	15 m	30 m	40 m	15 m	30 m	40 m
<i>Euclymene oerstedii</i> (Claparede, 1836)	5					7												
<i>Polyophthalmus pictus</i> (Dujardin, 1839)		5				7			75			40						
<i>Scelerobellus minutus</i> Grube, 1863					5													
<i>Amphirrite variabilis</i> (Risso, 1826)	10	5		5		14			5			30						
<i>Theosomma oerstedii</i> (Claparede, 1864)																		
<i>Polycirrus aurantiacus</i> Grube, 1860																		
<i>Terebellella lapidaria</i> Linnaeus, 1767		5				7												
<i>Terebellides stroemii</i> Sars, 1835	70	15			105	40			50			70			5		20	5
<i>Amphiglena mediterranea</i> (Leyding, 1851)																		
<i>Branchiommia bombyx</i> (Dalyell, 1853)	10	5	5			27			5			30			5		5	20
<i>Sabella fabricii</i> Kroyer, 1856																		
<i>Sabella pavonina</i> Savigny, 1820		10				7												
<i>Jasminatra caudata</i> (Grube, 1863)									20			20						
<i>Janita fimbriata</i> (Delle Chiaje, 1822)						14												
<i>Ficopomatia enigmatica</i> (Fauvel, 1923)																		
<i>Hydroides pseudoncinata</i> Zibrowius, 1968																		
<i>Placostegus crystallinus</i> Zibrowius, 1968																		
<i>Pomatoceros triquetus</i> (Linnaeus, 1865)																		
<i>Serpula concharum</i> Langerhans, 1880	5	10				7												
<i>Serpula vermicularis</i> Linnaeus, 1767		10				7												
<i>Vermiliopsis infundibulum</i> (Gmelin, 1788)	5	10	5			14			25			50			35		100	45
<i>Vermiliopsis labiata</i> (Costa, 1861)																		
<i>Protula</i> sp.																		
Spirorbidae																		
Polygordinae																		
S	26	29	21															
N	217	143	54															
A	1,085	715	270						1,970			285			525		505	
d	4,64	5,64	5,01						6,33			3,68			4,21		5,37	
H*	3,87	4,04	4,01						3,81			3,21			3,81		3,74	
J*	0,82	0,83	0,92						0,81			0,71			0,91		0,90	
									0,85			0,71			0,91		0,90	



**Fig. 2** Biocoenotic parameters (*above*) and diversity indices (*below*) for each depth level (15, 30, 40 m) and stations in summer. *d* Margalef richness, *H'* Shannon-Weaver index, *J'* Pielou's evenness, *S* number of species, *N* number of individuals

### Abundance of polychaete fauna

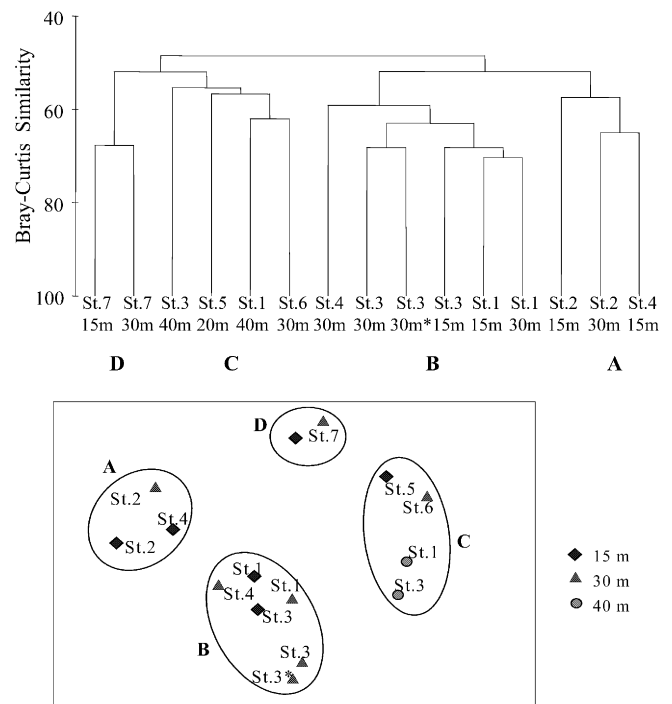
Concerning the spatial distribution, MANOVA showed that both depth and site had a significant effect ( $F=15.94$ ,  $P=0.001$  and  $F=13.30$   $P=0.001$ , respectively). The Fisher PLSD test indicated that differences exist between the three depth levels (15, 30 and 40 m) and between stations 2 and 4 on the one hand, and the rest of the stations on the other. Stations 2 and 4 are discriminated mainly due to the presence of high numbers of spirorbids. The decrease in polychaete abundance with depth is probably related to the algal vertical zonation: filamentous algae dominate in shallow waters, and encrusting algae in deep.

### Composition and diversity of polychaete fauna

The spatial fluctuation of the diversity indices and of the total number of individuals (*N*) and species (*S*) at each depth level is shown in Fig. 2. Richness values (*D*) ranged from 3.80 to 6.60, *H'* values from 3.28 to 4.35 and *J'* values from 0.72 to 0.91. These indices are a function of the number of species and individuals: high *N* and low *S* values result in low diversity indices. Spirorbids were excluded from the above calculation. They occurred at high numbers at stations 2 (15 and 30 m) and 4 (15 m), reaching abundances of 9,380, 910 and 725 individuals/m<sup>2</sup>, respectively, thus altering the diversity values.

### Affinity analysis

The affinity of the samples (station, depth) is given in Fig. 3. Both analyses (cluster and non-metric MDS) in-



**Fig. 3** Affinity of summer samples from different sites (stations 1–7) and depths (15, 30, 40 m). Results of cluster (*above*) and MDS (*below*) analysis based on Bray-Curtis similarity index

dicating a separation of the samples into four main groups at about 55% similarity degree. The stress value for the two-dimensional MDS configuration is 0.16. The one-way ANOSIM test gave global  $R=0.87$ , at a significance level of  $P<0.1$ , indicating a good discrimination between the four basic groups. Further examination in order to localize the differences among the groups by means of a pairwise test did not reveal any significant variation in *R* values, yet did show higher similarities between groups A and B, and between C and D.

SIMPER analysis identified 6–9 (13–19) species as responsible for 60% (90%) of the average similarity of groups, and 16–20 (38–46) species as responsible for 60% (90%) of the average dissimilarity of groups (Table 4).

The ABC curves (Fig. 4) show that, for most sites, the biomass curve was above that of abundance. Accordingly, the k-dominance pattern was produced. For station 2, however, the situation was reverse, and for station 4 the two curves coincide. This is due to the extremely high number of spirorbids, species with very small body size and thus negligible biomass.

### Temporal variation

#### Abiotic factors

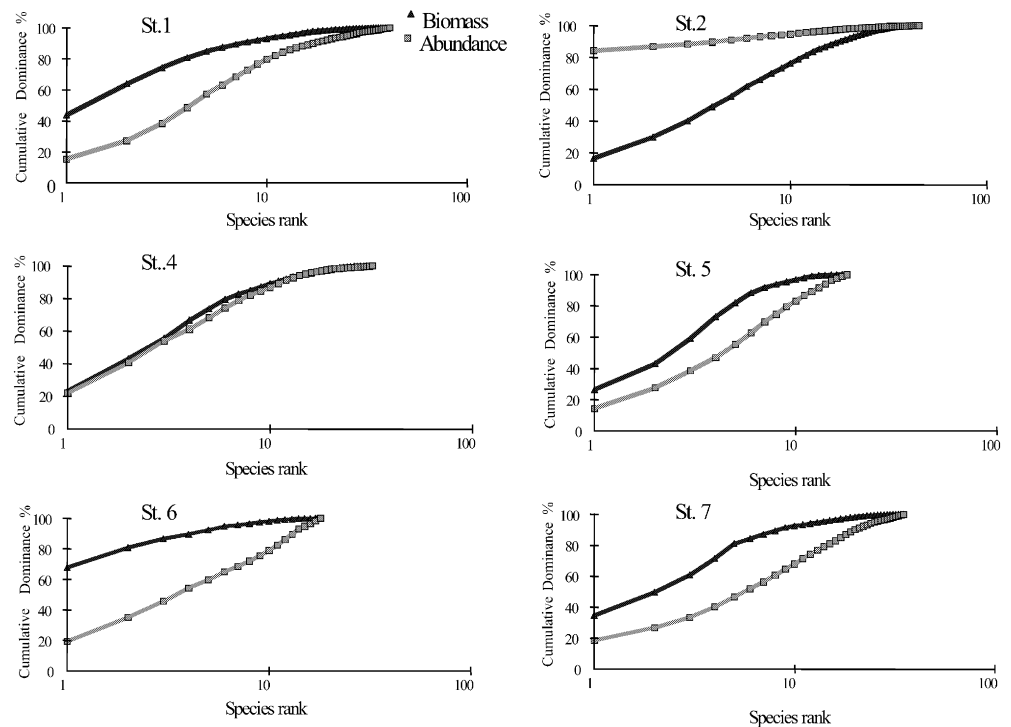
The seasonal pattern of the main abiotic parameters is summarized in Table 2. A seasonal thermocline was detected at about 20 m depth (end of July), while salinity and conductivity gained lower values during summer.



**Table 4** Percentage contribution of species to 60% similarity (S) within groups and /or dissimilarity (DS) among groups, according to the spatial multivariate analysis

Species	A		B		C		D		A:B		A:C		B:C		B:D		C:D	
	S=59.9	S=63.2	S=63.2	S=63.2	S=56.9	S=56.9	S=67.7	S=67.7	DS=48.1	DS=53.6	DS=49.4	DS=51.7	DS=48.1	DS=49.4	DS=51.7	DS=48.1	DS=48.1	
<i>Harmothoe ljunghmani</i>																		3.03
<i>Harmothoe spinifera</i>																		1.87
<i>Grubeosyllis limbata</i>									2.23					3.50		2.24		2.83
<i>Exogone naidina</i>									3.36					4.09				3.75
<i>Sphaerosyllis pirifera</i>			6.70		8.35				3.19		2.40			4.48				4.15
<i>Haplosyllis spongicola</i>																		
<i>Syllis amica</i>									2.06		2.20			3.26				
<i>Syllis cornuta</i>							5.61				2.65							
<i>Syllis gracilis</i>																		
<i>Syllis hyalina</i>	6.20				16.81		7.87		1.85									3.73
<i>Syllis prolifera</i>	7.83				9.25				2.02		3.00							4.08
<i>Syllis vittata</i>									2.04		2.22							
<i>Trypanosyllis coeliaca</i>									1.88									
<i>Trypanosyllis zebra</i>																		
<i>Nereis rava</i>	9.68				9.94		10.95		3.91		3.85			2.54		2.06		3.12
<i>Nereis zonata</i>	7.29								3.49		3.40			4.66		3.47		3.60
<i>Platynereis dumerilii</i>									3.07		4.61			4.21		2.23		2.00
<i>Glycera tessellata</i>	9.45								3.07		4.88			6.16		7.96		2.68
<i>Eunice vittata</i>									3.63		2.29			5.51				4.03
<i>Palola siciliensis</i>																		4.02
<i>Lysidice ninetta</i>									2.40		2.33			2.73		2.45		2.70
<i>Nematonereis unicornis</i>									2.15		3.45			2.31				3.60
<i>Dorvillea rubrovittata</i>																		2.00
<i>Scoletoma funchalensis</i>									2.04					3.80		3.11		4.21
<i>Polyophthalmus pictus</i>									2.25		2.56					2.38		1.85
<i>Polydora caeca</i>																		
<i>Amphitrite variabilis</i>																		
<i>Amphiglena mediterranea</i>									1.84		5.18			2.66		2.78		3.77
<i>Branchionoma bombyx</i>									2.26					4.69		2.59		2.70
<i>Serpula concharum</i>									6.51					3.34		2.35		2.70
<i>Pomatoceros triqueter</i>																		5.66
<i>Vermiltopsis infundibulum</i>									2.33		2.16					3.51		4.73
Spirorbidae	16.12				7.98		5.61		13.42		14.59			2.28		2.02		2.15

**Fig. 4** ABC curves for stations 1–7 (summer)



### Community description

The main biocoenotic parameters are presented at Table 5. Overall 1,133 individuals were counted, belonging to 66 species. 24 species, largely the same as those reported in the spatial survey, were dominant in the seasonal samples. *Syllis hyalina*, *Sphaerosyllis pirifera*, *Glycera tessellata* and *Vermiliopsis infundibulum* were dominant in all seasons.

### Abundance of polychaete fauna

Only depth had a significant effect (mANOVA:  $F=6.58$ ,  $P=0.002$ ). The Fisher PLSD procedure revealed that this effect was restricted to 40 m versus 15 and 30 m. No direct seasonal effect on polychaete abundance was detectable ( $F=2.30$ ,  $P=0.06$ ).

### Composition and diversity of polychaete fauna

The temporal fluctuation of the diversity indices, the total number of individuals ( $N$ ) and the number of species ( $S$ ) at each depth level is shown in Fig. 5. Richness values ( $D$ ) ranged from 3.91 to 6.48,  $H'$  values from 3.45 to 4.41, and evenness values ( $J'$ ) from 0.80 to 0.97. In general, diversity indices varied among seasons.

### Affinity analysis

The seasonal discrimination of samples is given in Fig. 6. Five groups (A–E) can be distinguished at about 50% similarity level. The stress value for the two-dimensional configuration is 0.12, indicating a good ordination (Clarke and Warwick 1994). The ANOSIM test confirms the results of the discriminative techniques ( $R=0.88$ ,  $P<0.1$ ). The pairwise test showed that the variations were significant in all cases ( $R$  ranging from 0.75 to 1).

SIMPER analysis identified 5–7 (10–17) species as responsible for 60% (90%) of the average similarity of groups, and 12–20 (22–38) species as responsible for 60% (90%) of the average dissimilarity of groups (Table 6).

The ABC curves for different seasons show biomass curves being always above those of abundance (Fig. 7). Therefore, the k-strategy pattern dominated throughout the year.

### Discussion

According to Pérès and Picard (1964), the Mediterranean infralittoral zone comprises two distinct communities: the photophilic alga community (at the upper level) and the sciaphilic alga community (at the lower level, often mentioned as precoralligenous and coralligenous). These two communities share some common characteristics: they both depend on the presence of different algal forms (Bellan-Santini et al. 1994) and are influenced by the hydrodynamism and light (Hong 1982; Marinopoulos 1988).

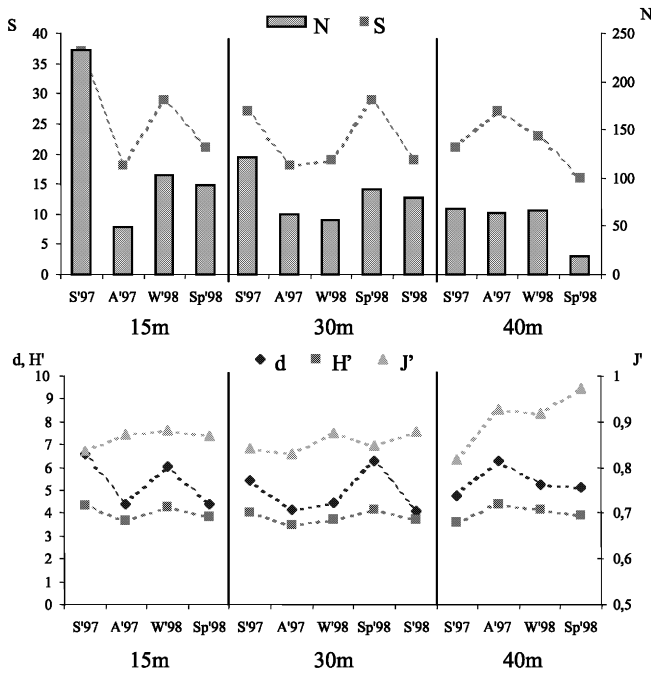


**Table 5** Polychaetes from seasonal samples of the sciaphilic alga community at station 3 (replicates of each depth level pooled), *N*, number of individuals, *S*, number of species, *A* ( $=N/m^2$ ) abundance, *F* frequency, *d* Margalef richness, *H'* Shannon-Weaver index, *J'* equitability index, 30 m\* sampling in July 1998

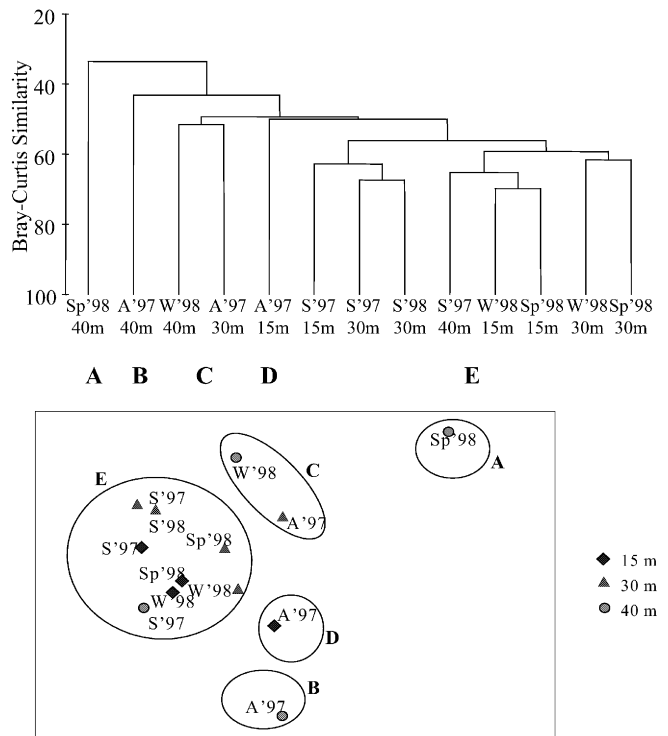
Species	Summer 1997			Autumn 1997			Winter 1998			Spring 1998			
	A		F	A		F	A		F	A		F	
	15 m	30 m	30 m*	40 m	15 m	30 m	40 m	15 m	30 m	40 m	15 m	30 m	40 m
<i>Laetmonice hystrix</i> (Savigny, 1820)													
<i>Harmothoe areolata</i> (Grube, 1860)													
<i>Harmothoe ljungmani</i> (Malmgren, 1867)													
<i>Harmothoe spinifera</i> (Ehlers, 1864)			5	5		5	5		5		5	10	5
<i>Scalisterosus fragilis</i> (Claparede, 1868)													
<i>Pholoe minuta</i> (Fabricius, 1780)													
<i>Chrysopetalum debile</i> (Grube, 1855)													
<i>Euphrasine foliosa</i> Audouin & Milne-Edwards, 1833		5		5		5	5		5		5	5	5
<i>Phylodoce madeirensis</i> (Langerhans, 1880)	5		5	10	5	15	27						
<i>Kefersteina cirrata</i> (Keferstein, 1862)	5		5	10		20	14		5		5	15	27
<i>Syllidia armata</i> Quatrefages, 1865													
<i>Pionosyllis lamelligera</i> Saint-Joseph, 1856	5	5	5	5	15	5	7		5		5	5	20
<i>Evogone naidina</i> Orsted, 1845	55	10	25	45		45			5		5	5	7
<i>Grubeosyllis limbata</i> (Claparede, 1868)	45	35	10	45		45							7
<i>Sphaerosyllis pirifera</i> Claparede, 1868	130	50	55	20	15	65	10	54	35	30	30	65	54
<i>Eusyllis blomstrandii</i> Malmgren, 1867	20	10	5	5		5			5				7
<i>Pterosyllis formosa</i> Claparede, 1863	5			5									
<i>Haplosyllis spongicola</i> (Grube, 1855)	5	5	10	15	5		7	7	10	5	15	34	34
<i>Syllis amica</i> Quatrefages, 1865													
<i>Syllis armillaris</i> Muller, 1771							20	14		5			7
<i>Syllis cirropunctata</i> Michel, 1909							5	7					
<i>Syllis cornuta</i> Rathke, 1843	35	5	25	20		55			15	10	5	5	40
<i>Syllis hydina</i> Grube, 1843	120	95	65	105	30		25	40	10	30	25	50	54
<i>Syllis krohnii</i> Ehlers, 1864	5			5		5		7					7
<i>Syllis prolifera</i> Krohn, 1852	65	10	15	45	15	15	27	27	25	10	5	20	25
<i>Trypanosyllis coeliaca</i> Claparede, 1868	10	10	20	5	10		15	20	5	20		27	46
<i>Trypanosyllis zebra</i> (Grube, 1860)	15	5	5	15	10	5	25	46	20		15	5	20
<i>Ceratonereis costae</i> (Grube, 1840)							5	7					
<i>Nereis rava</i> Ehlers, 1868	100			5	30	5	35	46	35	40	20	15	40
<i>Nereis zonata</i> Malmgren, 1867	10	5		5	15	10	15	27	5	10	34	5	7
<i>Platynereis diamerilii</i> (Audouin & Milne Edwards, 1833)	20	30		35	55	30	15	54	15		40	5	7
Nereididae Heteronereis stage													
<i>Glycera tessellata</i> Grube, 1863	115	110	65	40	5	70	30	67	60	55	40	80	60
<i>Glycinde nordmanni</i> (Malmgren, 1865)	5			5									
<i>Goniada maculata</i> Orsted, 1843													
<i>Arabella tricolor</i> (Montagu, 1804)													
<i>Dorvillea rubrovittata</i> (Grube, 1855)	5			5									
<i>Eunicce oerstedii</i> Stimpson, 1854	5			5									
<i>Eunicce torquata</i> Quatrefages, 1865							10	7					
<i>Eunicce vittata</i> (Delle Chiaje, 1929)	20	65	30	5	50	35	10	27	65	5	35	40	40
<i>Lysidice ninetta</i> (Audouin & Milne Edwards, 1833)	30	15		35	40	5	5	14	15	20	5	20	54
<i>Nematonereis unicomis</i> (Grube, 1840)	5		5	10	5	5		14		5		10	7
<i>Lumbrineris coccinea</i> (Renier, 1804)	5		5	5									
<i>Scoletoma junchalensis</i> (Kinberg, 1865)	35	15	5	35	20	10	10	34	35	10	5	15	46
<i>Onuphis</i> sp.				5					5				7
<i>Laonice cirrata</i> (Sars, 1851)	5			5									
<i>Polydora caeca</i> (Orsted, 1843)				5			5	7					
<i>Polyophthalmus pictus</i> (Dujardin, 1839)				5			5	14					

**Table 5** (continued)

Species	Summer 1997			Autumn 1997			Winter 1998			Spring 1998		
	A		F	A		F	A		F	A		F
	15 m	30 m	30 m*	15 m	30 m	40 m	15 m	30 m	40 m	15 m	30 m	40 m
<i>Pterusa</i> sp.												
<i>Amphitrite variabilis</i> (Risso, 1826)	10	10	10	5	30							7
<i>Theostoma oerstedii</i> (Claparede, 1864)	5				5							20
<i>Polycirrus aurianticus</i> Grube, 1860												7
<i>Terebellides stroemi</i> Sars, 1835	25				15	5	7					
<i>Amphigena mediterranea</i> (Leyding, 1851)	120	35	20	15	65	20	20	5	15	46	10	5
<i>Branchiommia bombyx</i> (Dalyell, 1853)	15	25	15		35				15	14		
<i>Sabella pavonina</i> Savigny, 1820	5				5	5	7	10	7	7		
<i>Hydroïdes pseudouncinata</i> Zibrowius, 1968									10	14		
<i>Placostegus crystallinus</i> Zibrowius, 1968												
<i>Pomatoceros lamarekii</i> (Quatrefages, 1865)												
<i>Pomatoceros triquetus</i> (Linnaeus, 1865)	30				30	10	30	5	5	14	5	20
<i>Jasmineira candela</i> (Grube, 1863)												
<i>Jania fimbriata</i> (DelleChiaje, 1822)	5	5			5	5	7	5	15	20		7
<i>Serpula concharum</i> Langerhans, 1880	5	15			5		7					5
<i>Serpula vermicularis</i> Linnaeus, 1767	5				5		7		20	14		15
<i>Vermiltopsis infundibulum</i> (Gmelin, 1788)	65	10	15	15	50	15	34	15	20	34	25	54
<i>Protula</i> sp.												
S	37	27	19	5	5	10	20					
N	233	122	80	18	18	27		29	19	23	21	16
A	1,165	610	400	49	49	63		103	56	66	93	19
d	6.61	5.41	4.1	4.37	4.12	6.28		530	285	350	510	100
H'	4.36	4.01	3.73	3.64	3.46	4.41		6.04	4.47	5.25	4.41	5.1
J'	0.84	0.84	0.88	0.87	0.83	0.93		0.88	0.87	0.92	0.87	0.97



**Fig. 5** Biocoenotic parameters (*above*) and diversity indices (*below*) over an annual cycle at station 3 (15, 30, 40 m depth). *S* summer, *A* autumn, *W* winter, *Sp* spring, *d* Margalef richness, *H'* Shannon-Weaver index, *J'* Pielou's evenness, *S* number of species, *N* number of individuals

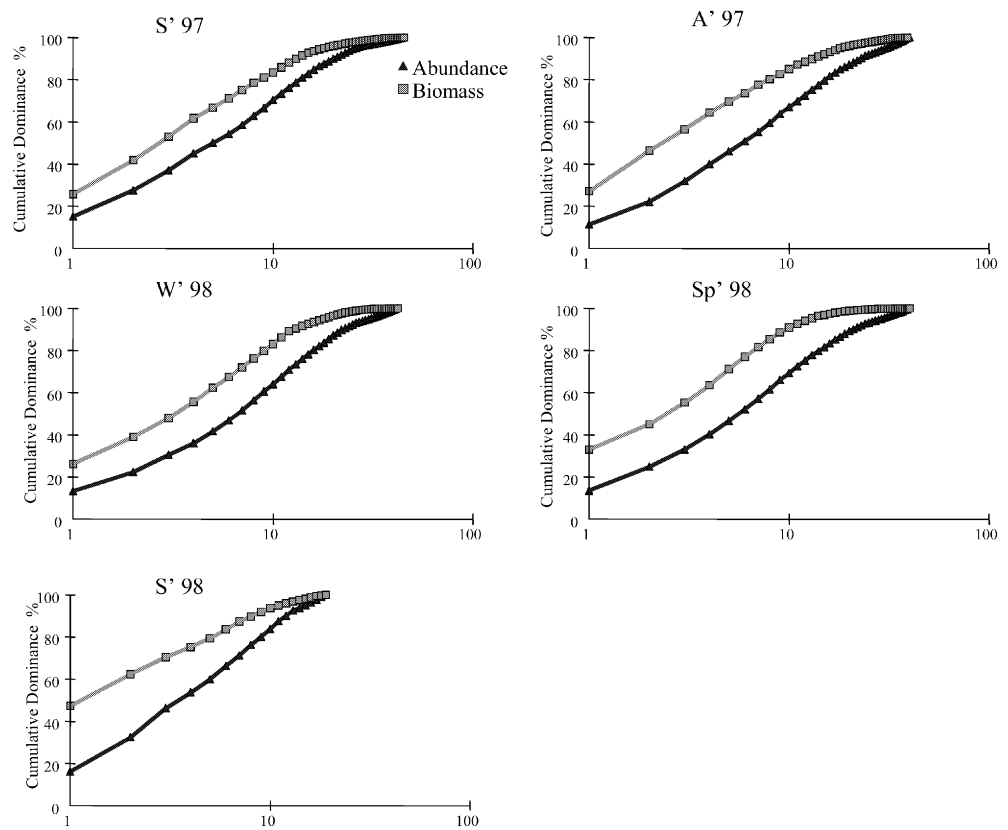


**Fig. 6** Affinity of seasonal samples from different depths at station 3. Results of cluster (*above*) and MDS (*below*) analysis based on Bray-Curtis similarity index

Bellan (1964, 1969) studied the photophilic alga community and found 128 species of Polychaeta which were classified, according to their ecological preferences, to 11 discrete “stocks”. Cardell and Gili (1988) studied the facies of *Lithophyllum tortuosum* and recorded 71 species. They concluded that this assemblage is very homogeneous, both spatially and temporally. However, *Sphaerosyllis pirifera* and *Platynereis dumerilii* showed an increase in numerical abundance in summer. Most species were common in the hard substrate stock (Bellan 1969), and especially within the photophilic alga community: some species were characteristic of the concretioned substrate (Laubier 1966; Sardà 1991). Frascchetti et al. (2002) studied the facies of *Cystoseira amentacea* and found 59 species of Polychaeta, most of which were common species among sublittoral photophilic algae (Sardà 1991). The same authors did not find any noticeable seasonal changes, with the exception of the large numbers of *Platynereis dumerilii* in summer. Chintiroglou (1996) reported 87 species associated with *Cladocora caespitosa* colonies at 5–18 m depth, and Damianidis and Chintiroglou (2000) recognized 48 species associated with *Mytilus galloprovincialis* assemblages in the upper infralittoral zone. Sardà (1991), in a study of hard substrate communities from 1 to 40 m depth, found 220 species and discriminated five distinct communities: the *Lithophyllum lichenoides* (with the lowest diversity), the shallow photophilic, the deeper photophilic, the *Posidonia oceanica* rhizomes and the infralittoral sciaphilous community. The contributions of the different ecological

stocks (Bellan 1969) to these communities change according to habitat complexity. In our study, we found 79 species of polychaetes in the sciaphilic alga community (15–40 m), while Marinopoulos (1988) found 36 (21 common) at similar depths. Most of these species are members of the photophilic alga community, but there is also a significant contribution of cryptic, hard substrate, soft substrate and coralligenous (concretioned substrate) species. It seems that polychaetes have a large ecological tolerance and that their occurrence is largely dependent on substrate availability and complexity (Bellan 1964, 1969; Hong 1982). We found clear spatial differences in polychaete distribution, while temporal differences were less apparent. The spatial distribution of polychaetes largely corresponds with the occurrence of different algal facies. We have noted a high affinity between stations 1 and 3 at all depth levels. This could be expected, since these two sites share some common characteristics such as the high inclination (~90°) and large bathymetrical extension of the rocky substrate. Station 7 is separated, probably due to abiotic parameters (low salinity). Its relatively moderate inclination sets station 7 near to stations 5 and 6, while the sharpest slope ranks stations 2 and 4 closer to stations 1 and 3. The depth level of 40 m (stations 1 and 3) shows high affinity with stations 5 and 6, as it hosts a fairly low number of polychaete species and individuals. SIMPER analysis showed that both the similarities within groups and the dissimilarities between groups were the result of small contributions of a large number of species, indicating a diverse community with a

**Fig. 7** ABC curves for different seasons (station 3). *S* summer, *A* autumn, *W* winter, *Sp* spring



highly complex structure (Dahl and Dahl 2002). This heterogeneity may result from the presence of several algal species of different architecture (Chemello and Milazzo 2002). Fan-shaped structures and filamentous forms dominate group A, filamentous forms group B, encrusting forms group C, and filamentous bush-like encrusting forms group D. Many authors have stated that polychaetes are not related to specific algal species, but to specific algal architectures (Naim and Amoureux 1982; Sardà 1988; Gambi et al. 1995; Fraschetti et al. 2002). Groups A and B are characterized by high diversity and abundance in comparison to groups C and D. It should be noted that the high abundance in group A is mainly due to the presence of high numbers of spirorbids attached to the thalli of *Padina pavonica*. Spirorbids are capable of settling immediately after release from parental tubes and are typically multiannual in the sense of Fauchald (1983), living in unstable environments. They probably perish when the thalli of *Padina pavonica* decay after mid-September (Diapoulis and Koussouris 1988). Spirorbids strongly influence the discrimination of group A, the ABC analysis and the diversity indices. Another difference was found in the polychaete fauna associated with the two filamentous Rhodomelacea, *Womersleyella setacea* and *Polysiphonia* sp. An abundant and diversified polychaete is associated only with the former. *Womersleyella setacea* is an introduced and probably invasive species (Boudouresque and Verlaque 2002) which has spread over the Mediterranean (Verlaque 1989; Airoldi et al. 1995) and the northern Aegean Sea (Athanasiadis

1997). It forms paucispecific populations with increasing turf development. These turfs trap sediment, forming a stratum that prevents the development of other algal species on the rocky substrate (Piazzi and Cinelli 2000). However, the entrapped sediment increases the complexity of the system, offering suitable microhabitats for the settlement of many soft-sediment polychaete species.

The study of temporal changes in polychaete distribution revealed that summer is distinct from the other three seasons. Winter and spring form an even group, while autumn branches out according to depth. This is the case for the upper depth levels (15 and 30 m), where *Womersleyella setacea* dominated throughout the year. This species is capable of continuous vegetative reproduction (Athanasiadis 1997), creating a very stable and homogenous habitat which may contribute to the lack of seasonality. The image is much more complicated at the 40-m depth level, where the dominant algae were represented by various species of Corallinacea and Peyssonneliacea. Here, summer samples were similar to winter ones, while autumn and spring samples discriminated.

According to the relevant literature, there is no distinct seasonality in the lower infralittoral zone, in contrast to the upper one (Hong 1982; Marinopoulos 1988). However, a discrimination of summer is frequently observed (Damianidis and Chintiroglou 2000) and may be due mainly to the massive recruitment of a few species, e.g. *Platynereis dumerilii* (Cardell and Gili 1988; Fraschetti et al. 2002). In our study, the bathymetric distribution of polychaetes changed with season, while the species in-

**Table 6** Percentage contribution of species to 60% similarity (S) within groups and/or dissimilarity (DS) among groups, according to the temporal multivariate analysis

Species	C		E		A:B		A:C		A:D		A:E		B:C		B:D		B:E		C:D		C:E		D:E	
	S=51.5	S=58.9	DS=71.4	DS=57.8	DS=67.7	DS=67.8	DS=57.8	DS=53	DS=57.1	DS=54.5	DS=50.2	DS=49.9												
<i>Harmothoe spinifera</i>																								
<i>Phyllodoce madeirensis</i>					4.97	2.47														2.96				
<i>Syllidia armata</i>		6.02																				2.37		
<i>Grubeosyllis limbata</i>		5.40																				2.70		2.93
<i>Exogone naidina</i>																								
<i>Haplosyllis spongicola</i>																								
<i>Syllis amica</i>		10.34			6.27	7.54														5.34		2.41		2.61
<i>Syllis armillaris</i>																						4.73		3.22
<i>Syllis cirropunctata</i>																								
<i>Syllis cornuta</i>																								
<i>Syllis hyalina</i>																								
<i>Syllis krohni</i>		11.46			5.67	6.29														4.50		3.74		5.35
<i>Trypanosyllis coeliaca</i>		6.98			4.97	2.86																6.26		3.02
<i>Trypanosyllis zebra</i>						2.98														4.46		3.07		
<i>Pionosyllis lamelligera</i>																						2.47		
<i>Nereis rava</i>																								
<i>Nereis zonata</i>																								
<i>Ceratonereis costae</i>					9.41	4.80														3.89		3.60		3.76
<i>Platynereis dumerilii</i>	8.54																			2.81		2.55		
<i>Heteronereis stage Nereitidae</i>	15.12				8.11	2.64														4.46		5.47		2.36
<i>Goniada maculata</i>	17.08	13			3.14	8.94														7.21				7.68
<i>Eunice vittata</i>																								
<i>Nematonereis unicoloris</i>		6.04				3.39														2.91		3.52		5.78
<i>Lumbrineris coccinea</i>	16.16	6.47				3.18														2.85		2.45		6.34
<i>Polydora caeca</i>																				8.44				2.64
<i>Polycirrus aurantiacus</i>																				2.84				
<i>Terebellides stroemi</i>		2.33				2.48														2.10		2.44		2.85
<i>Amphiglena mediterranea</i>																				2.13				
<i>Branchiomma bombyx</i>																				4.95				
<i>Sabella pavonina</i>	10.77	6.92			3.14	3.42														2.62		2.57		2.84
<i>Serpula concharum</i>																				2.62				
<i>Serpula vermicularis</i>																				2.62				2.64
<i>Placostegus crystallinus</i>																								
<i>Pomatoceros tamarckii</i>		3.69			3.14	2.80														2.87		2.94		
<i>Vermiliopsis infundibulum</i>					3.14	4.54														2.38		3.78		3.78
<i>Hydroides pseudouncinata</i>		4.66			6.27															4.55		2.35		2.35

ventory at the stations remained unchanged throughout the year. Marinopoulos (1988) also found seasonal changes in the abundance of polychaetes at different depths, with the same species (*Syllis hyalina*, *Syllis prolifera*, *Syllis vittata*, *Platynereis dumerilii* and *Sphaerosyllis pirifera*) being abundant at low depth during summer and in deeper waters during winter. It seems that the seasonality of the sciaphilic alga community is mainly achieved by a vertical rearrangement of the abundances of different polychaete species.

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