

Structure and functions of Polychaetofauna living in *Mytilus galloprovincialis* assemblages in Thermaikos Gulf (north Aegean Sea)

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Abstract – The purpose of this study is to examine the Polychaetes populations of the mussel *Mytilus galloprovincialis* Lamarck 1819 assemblage in Thessaloniki Bay (Perea, Neoi Epivates, Agia Triada) in space and time. Forty-eight Polychaetes species, which belong to 16 families, were identified among 10 593 individuals. The different distribution in space and time can be attributed to the life cycles of the Polychaetes, and also to the various biotic interactions. In general, the abundance follows the succession of the seasons, with some deviations though. Thus, the samples can be divided into two major groups, the winter and summer samples. The structure of the feeding guilds of the Polychaetes population was also investigated and 9 different feeding guilds were identified. The microphagous, sedentary Polychaetes were the dominant guild, whilst the carnivores were the most abundant among the macrophagous. No major differences were observed, as regards the composition of the feeding guilds. The study of the structure of the polychaetofauna showed similar diversity with that of other Mediterranean regions. This fact implies that the polychaetofauna of the *M. galloprovincialis* assemblages in the Mediterranean Sea has a stable structure and shows a certain resemblance. Furthermore, the polychaetofauna includes species known as capable of living in polluted water as well as others that are more sensitive in such conditions. Therefore, the biomonitoring of the examined regions proves to be essential for obtaining valuable information about the state of their waters. © 2000 Ifremer/CNRS/IRD/Éditions scientifiques et médicales Elsevier SAS

Polychaeta / infralittoral / hard substratum / trophic relations / Aegean Sea

Résumé – Structure et fonction des Annélides Polychètes des assemblages de *Mytilus galloprovincialis* dans le golfe de Thermaikos (mer Egée Nord). Le but de la présente étude concerne l'examen de la population des Annélides Polychètes de la moule *Mytilus galloprovincialis* Lamarck 1819 dans la baie de Salonique (Perea, N. Epivates et Agia-Triada) dans ses dimensions spatiale et temporelle. Pour un total de 10 593 individus, 48 espèces de Polychètes ont été déterminées, représentant 16 familles. L'abondance des Polychètes présente des variations en fonction de l'espace et du temps, ce qui est lié à leur cycle de vie, outre des interactions biotiques qui se développent entre les Polychètes et les autres organismes. Les variations de l'abondance suivent la succession des saisons. Ainsi, les échantillons se regroupent en deux groupes principaux, en fonction de la saison. Parallèlement, une étude de la structure des types trophiques des Polychètes a été réalisée. Cette partie de notre étude a mis en évidence la présence de neuf types trophiques. Au groupe principal, appartiennent les microphages, Polychètes sédentaires, tandis que, parmi les macrophages, dominent les carnivores. Les échantillons ne se différencient pas significativement en fonction de la constitution des types trophiques. L'étude de la constitution de la faune des Polychètes a mis en évidence une variabilité (nombre des espèces, indice de Shannon, stabilité)

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similaire à celle observée dans d'autres régions de Méditerranée, fait en faveur de la stabilité et de l'homiomorphie des phases de *M. galloprovincialis* en Méditerranée. En même temps, la constitution de la faune des Polychètes comporte des espèces caractérisées par leur résistance vis-à-vis de la pollution, et des espèces sensibles à la pollution. Cette observation indique que la « biosurveillance » de la phase de *M. galloprovincialis* peut fournir des informations considérables quant à la pureté des eaux. © 2000 Ifremer/CNRS/IRD/Éditions Scientifiques et médicales Elsevier SAS

Polychètes / zone infralittorale / substrat rocheux / relations trophiques / mer Égée

1. INTRODUCTION

The assemblages of *M. galloprovincialis* belong to those that can develop in polluted, moderately polluted and clean waters ([5, 6, 21, 23, 25, 31, 35, 37, 38] and others). Therefore, the biomonitoring of these assemblages can be a reliable source of information about the impact of pollution on hard substrate assemblages. According to Wenner [40], the structure of mussel communities can be a powerful bioindicator in the biomonitoring of the pollution of degraded marine areas.

There is adequate information about the structure of *M. galloprovincialis* assemblages from various regions in the Mediterranean Sea, especially from the western Mediterranean coasts [5–7, 15, 16, 27, 28, 36–38]. However, the information on the Aegean Sea is relatively limited. The first attempts to deal with this issue were published by Kocatas [23] and Topaloglu and Kihara [35].

In recent years, a research team of the Aristotle University of Thessaloniki has been funded by the Greek Ministry of Development to conduct a scientific programme to evaluate pollution in the Thermaikos Gulf, based on the examination of the composition of the artificial hard substrate in the Gulf. A part of this research was completed and published [12, 26] as preliminary results on the structure of *M. galloprovincialis* populations. In addition, Lantzouni [25] and Damianidis and Chintiroglou [14] provided further information on the structure of the amphipodofauna and the Polychaetofauna of these assemblages, respectively.

The aim of this study was to gather certain facts about the structure and functions of the Polychaetofauna living in the *Mytilus galloprovincialis* assemblage on the eastern coast of Thessaloniki Bay. These

facts are essential for the support of a pollution biomonitoring programme in Thermaikos Gulf, which is heavily affected by industrial and urban waste.

2. MATERIALS AND METHODS

2.1. Selection of the sampling sites

The selection of the three sampling sites was based on their historical background, as well as on the exposure of the *Mytilus galloprovincialis* assemblages and the depth where they had settled. Out of all areas along the east coast of Thessaloniki Bay with artificial hard substrate, three appeared to show an equal bathymetric distribution of the *M. galloprovincialis* populations and corresponding exposure; they were the piers of Agia Triada, Neoi Epivates and Perea (figure 1). These piers were constructed 25 years ago, made of cement and based on a number of vertically-built cement columns, which constitute the substrate for the growth of the musselbeds. At these sampling sites the populations of *M. galloprovincialis* modulate a uniform physiognomic aspect, with great numbers of mussels occupying the area that extends from the lower level of the infralittoral zone down to a depth of 2.5 m.

2.2. Physico-chemical factors

During this study, factors such as salinity, conductivity, water clarity, dissolved oxygen, temperature and total hydrodynamics were measured. All measurements were made with a WTW salinity–conductivity–O₂–meter and Lovibond Checkit (pH–meter) micro-electronic equipment. The water transparency

was determined with the Secchi disc. The evaluation of the effect of hydrodynamics according to Kaandorp [22] was based on the corrosion of plaster in the water. The measurements of the physico-chemical factors were conducted at each sampling site on a monthly basis.

2.3. Sampling methods

Sampling was carried out by Scuba diving. Samples were taken by means of the sampling methods described by Chintiroglou and Koukouras [10]. The area covered by this sampler is 400 cm² (20 × 20 cm), which is the minimum necessary quadrat area for the investigation of the hard substrate [5, 31, 34, 39]. During each sampling period, 5 replicates were taken. The 60 samples, were collected during winter and summer of 1994 and 1995. After sampling, the specimens were preserved in a 10% formalin solution and were transferred to the laboratory for further treat-

ment. The mussels contained in each sample were then counted and afterwards separately weighed, together with their shells, in order to estimate their average biomass. Tsuchiya and Nishihira [36] consider these data as important biotic factors for the composition of the *M. galloprovincialis* assemblages. All samples were collected by the same Scuba diver, so that the homomorphy of the sampling was guaranteed [3].

2.4. Classification of the Polychaetes' feeding guilds

The families of Polychaetes that have been identified in our samples have been classified in eight feeding guilds, based on the models of Fauchald and Jumars [17], and then divided into three categories. The first one divides the Polychaetes into macrophagous and microphagous, according to the quantity of food they consume. The second category divides them into carnivores and herbivores, and the third category in

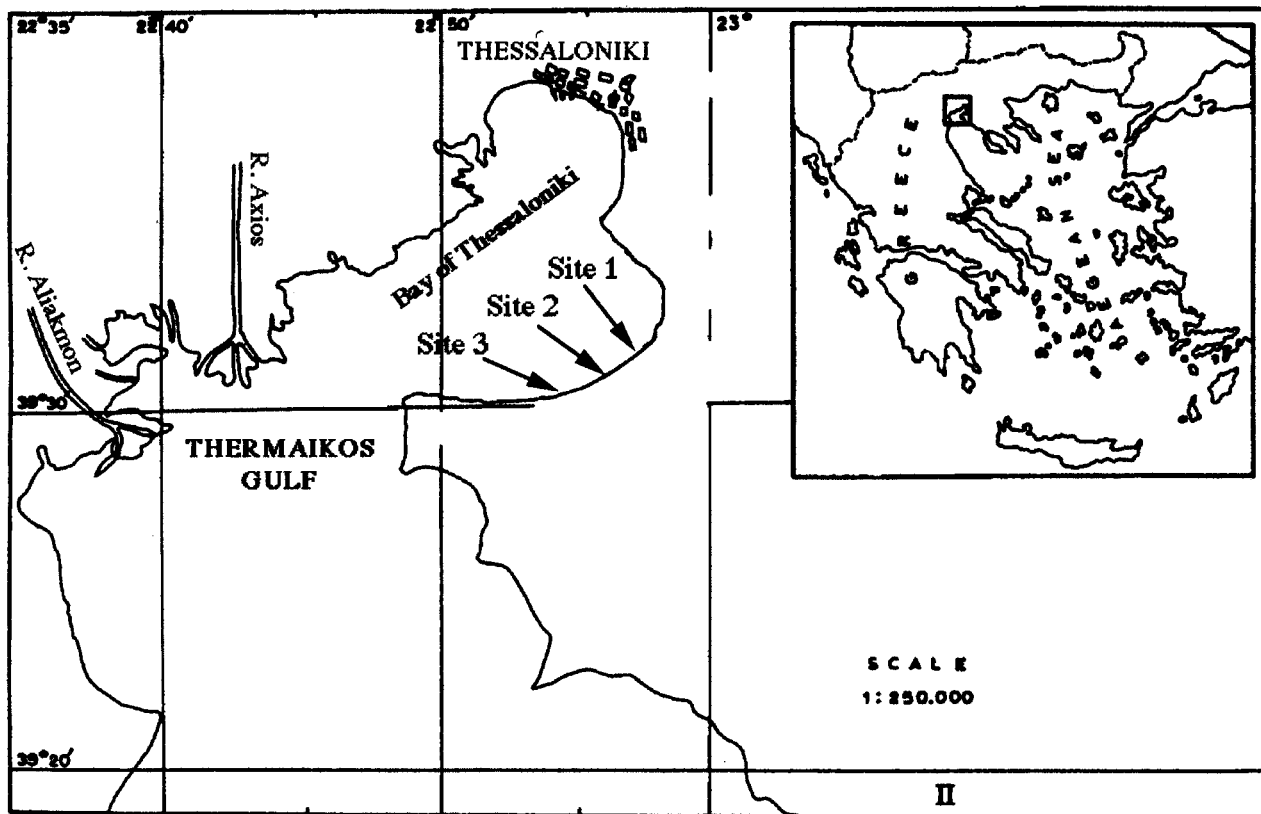


Figure 1. Map of the three sampling sites: Site 1 = Perea (P); Site 2 = Neoi Epivatres (NE); Site 3 = Agia Triada (AT).

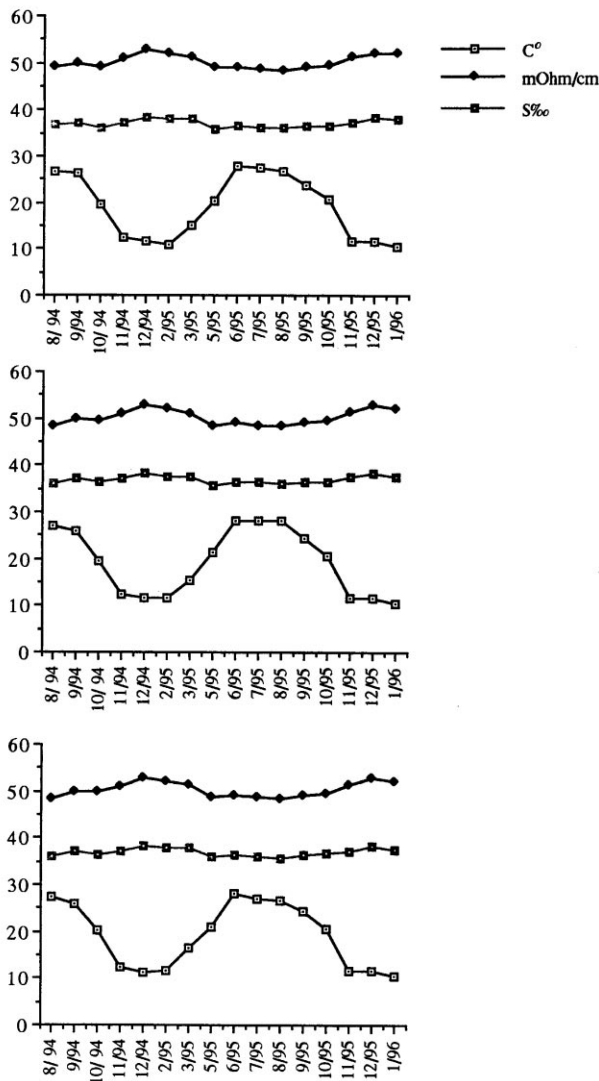


Figure 2. Results of the measurements of the main physico-chemical factors at each sampling site: temperature (°C), conductivity (mOhm·cm⁻¹) and salinity (S ‰).

motiles, discretely motiles and sessiles, according to the activity they show while consuming their food.

2.5. Data analysis

The presentation of the Polychaetofauna of the *M. galloprovincialis* assemblages was made by the methods proposed and used by Bellan-Santini [5], Soyer [33] and Marinopoulos [27]. This method compares

species of different ecological groups in terms of bionomic coefficients. Species diversity (*H'*) was calculated by Shannon's formula and evenness (*J'*) was measured by the formula $H'/\log_2 S$ [13, 21, 27]. Seasonal differences in the mean numbers of individuals were tested using two-way and one-way Anova and multiple comparisons of mean values (Fisher PLSD test). All data were then converted to logarithms. The non-parametric test Spearman rank correlation coefficient (r_s) [32] was used to determine the relationship between the number of mussels and their biomass with the abundance of the Polychaetofauna.

Eventually, the affinity of the sampling sites, in terms of the mean abundance of the samples, was determined with the use of the euclidean distance and the grouping coefficient of Ward's minimum-variance method. A similar methodology was followed by other studies of the hard substrate communities [6, 16, 21].

3. RESULTS

3.1. Physico-chemical characteristics of the stations

3.1.1. Conductivity, salinity and temperature

Conductivity, salinity and temperature do not vary significantly in the three sampling stations (figure 2). In general, the pattern of the fluctuation of these values in time appears to be similar in all stations. The conductivity values do not show any significant fluctuation. On the other hand, the salinity values that were expected to reach their maximum in the summer months show their lowest values between May and October. The annual fluctuation of the measured salinity is in accordance with the facts presented by Anagnostou [1], Galinou-Mitsoudi [19] and Orfanidis [30]. These lower values appear to be the result of the inflow of freshwater from the estuary systems of the rivers Axios, Loudias, Aliakmon and Gallikos. The SSE winds, which are dominant in summer, lead these freshwater masses through surface currents to the eastern coast of Thermaikos Gulf [20, 24].

3.1.2. Hydrodynamics

As mentioned above, the degree of exposure, i.e. the intensity of hydrodynamics, is one of the most impor-

tant factors involved in the study of the hard substrate communities.

The hydrodynamics effect is defined as the loss (%) of weight observed in previously weighed plaster pieces. This method revealed that, during the period when the southern and southeastern winds dominate in the Thermaikos Gulf, the weight loss in Agia Triada and in Neoi Epivates was 48 %, while the corresponding value in Peraia was 65 %. These results indicate that the hydrodynamics effect is stronger in Peraia than in the other sites. However, these results are reversed when the winds blow in the opposite direction. The hydrodynamics effect is then stronger in Agia Triada and in Neoi Epivates than in Peraia.

3.1.3. Water transparency

The water transparency at the sampling sites could be characterized as satisfactory and at certain times even excellent, since the bottom was clearly visible at each biotope. It should be noted though that when SSE and NNW winds blow in the area, the water transparency is limited due to water turbulence and the incoming material from the northern coast.

3.1.4. Dissolved oxygen and pH

These two factors showed no significant fluctuation in time. With regard to pH, the values varied around 8, while the values for dissolved oxygen ranged from 6.5 to 8 ppm.

In conclusion, the abiotic factors measured in all sampling sites revealed a similar fluctuation in time. Therefore, eventual changes in the composition of the *M. galloprovincialis* assemblages should not be attributed to any of those factors.

3.2. Polychaetofaunal composition

48 Polychaete species were identified in this study (tables I, II, III), 27 of which can be characterized as very common, since their proportional representation in the total number of samples exceeds 50 %. Ten species, whose proportional representation ranges from 25 % to 50 %, can be characterized as common.

– The presence of *Prionospio (Prionospio) steenstrupi*, the most frequently represented species in the *M. galloprovincialis* assemblage (18.1 %), is the most remarkable. Its mean and partial dominance are the

highest in Peraia and Neoi Epivates and second in Agia Triada. This species is notably abundant in the summer samples and especially in the summer of 1994, whereas in the winter samples it is only found in small numbers. Generally, the presence of this species is imminently affected by its life cycle and its particular reproductive pattern that demands multiple reproductive efforts within a year [14, 18].

– There is one species that shows the highest mean abundance in summer samples, even though its general frequency in the total of the samples is not considerable (7.5 %). That is *Schistomeringos rudolphii* whose mean abundance reached 18.2 % in the summer of 1995 in Neoi Epivates. The size of these individuals was notably small in these samples, probably as a result of a successful reproductive effort, which explains their high numbers.

The family with most species present in the samples is Serpulidae, which is represented by eight species; the most abundant of them is *Serpula vermicularis* (16.9 % in all samples). This species was found in every sample in all sampling sites. Its proportional representation is recorded as the second highest in Peraia and Neoi Epivates and as third in Agia Triada.

3.3. Abundance and diversity of the Polychaetofauna

3.3.1. Abundance

The comparison of the Polychaetes' abundance in time and in space was based on the examination of the null hypothesis that the abundance of the Polychaetes does not differ significantly (figures 3, 4). The two-way and one-way Anova tests showed that the abundance of the Polychaetes is not equally distributed in the samples either in time or in space ($F = 2.5$, $df = 1/5$, $P = 0.04$). One-way Anova was used to detect the exact differences and showed an unequal distribution of the abundance of the Polychaetes in winter as well as in summer samples ($F = 14.6$, $df = 5/23$, $P = 0.0001$ in winter samples and $F = 10.5$, $df = 5/22$, $P = 0.0001$ in summer samples). Fisher PLSD test was also carried out in order to reveal those differences in winter samples and the result (Fisher PLSD, 0.4) indicated that all winter samples are significantly different, with the exception of some pairs of samples, more specifically PE.94/

Table I. Polychaetes of the *M. galloprovincialis* assemblage in the bay of Thessaloniki from the total number of samples at Peraia sampling site. Number of individuals (N'), Mean abundance (Am), Partial mean dominance (Dmp), Shannon index (H') and Equitability index (J').

<i>Polychaetofauna</i>	Winter 94		Summer 94		Winter 95		Summer 95		Total	
	Am	Dmp	Am	Dmp	Am	Dmp	Am	Dmp	Am	Dmp
<i>Harmothoe impar</i>							0.40	0.42	0.50	0.10
<i>Harmothoe reticulata</i>	2.40	3.66	5.40	3.06			0.40	0.42	10.25	2.07
<i>Harmothoe spinifera</i>	11.00	16.77	0.60	0.34	1.20	2.08	2.00	2.09	18.50	3.74
<i>Eumida sanguinea</i>	0.20	0.30	0.20	0.11	1.80	3.13	1.20	1.25	4.25	0.86
<i>Genetyllis rubiginosa</i>	0.60	0.91	2.80	1.59			0.40	0.42	4.75	0.96
<i>Kefersteinia cirrata</i>			13.60	7.71	4.60	7.99	22.40	23.38	50.75	10.27
<i>Ophiodromus pallidus</i>			1.20	0.68	1.00	1.74			2.75	0.56
<i>Syllidia armata</i>	11.00	16.77	23.60	13.38	0.40	0.69			43.75	8.85
<i>Exogone naidina</i>	0.20	0.30							0.25	0.05
<i>Syllis krohnii</i>	0.20	0.30							0.25	0.05
<i>Syllis prolifera</i>			1.40	0.79			0.20	0.21	2.00	0.40
<i>Ceratonereis costae</i>	0.20	0.30	0.20	0.11	1.80	3.13	0.40	0.42	3.25	0.66
<i>Neanthes caudata</i>							0.20	0.21	0.25	0.05
<i>Nereis zonata</i>	0.40	0.61	2.60	1.47	0.20	0.35			4.00	0.81
<i>Platynereis dumerilii</i>	0.20	0.30			0.20	0.35			0.50	0.10
<i>Lumbrineris coccinea</i>	0.40	0.61	0.20	0.11	0.40	0.69			1.25	0.25
<i>Lumbrineris funchalensis</i>			1.00	0.57			0.60	0.63	2.00	0.40
<i>Lysidice ninetta</i>			1.20	0.68	0.20	0.35	0.80	0.84	2.75	0.56
<i>Marphysa fallax</i>							0.20	0.21	0.25	0.05
<i>Marphysa sanguinea</i>	0.20	0.30	0.40	0.23					0.75	0.15
<i>Nematonereis unicornis</i>	0.20	0.30					1.20	1.25	1.75	0.35
<i>Schistomeringos rudolphii</i>	1.40	2.13	21.20	12.02	0.20	0.35	14.80	15.45	47.00	9.51
<i>Polydora caeca</i>	0.80	1.22	0.20	0.11	0.20	0.35	1.40	1.46	3.25	0.66
<i>Polydora ciliata</i>	1.40	2.13	0.40	0.23	0.40	0.69	2.80	2.92	6.25	1.26
<i>Prionospio steenstrupi</i>			62.80	35.60			6.00	6.26	86.00	17.40
<i>Cirriformia tentaculata</i>							0.20	0.21	0.25	0.05
<i>Cirratulus</i> sp.			3.00	1.70	1.80	3.13			6.00	1.21
<i>Chaetozone setosa</i>	1.40	2.13	0.60	0.34					2.50	0.51
<i>Caulleriella alata</i>					0.40	0.69	2.60	2.71	3.75	0.76
<i>Polyopthalmus pictus</i>	0.20	0.30			0.40	0.69			0.75	0.15
<i>Capitella giardi</i>					0.40	0.69			0.50	0.10
<i>Heteromastus filiformis</i>			0.20	0.11			3.40	3.55	4.50	0.91
<i>Sabellaria spinulosa</i>	0.80	1.22	0.60	0.34	0.20	0.35	0.40	0.42	2.50	0.51
<i>Amphitrite variabilis</i>	0.60	0.91	6.20	3.51	0.60	1.04	1.40	1.46	11.00	2.23
<i>Terebella lapidaria</i>					1.20	2.08	12.00	12.53	16.50	3.34
<i>Hydroides elegans</i>	0.20	0.30	2.20	1.25	10.20	17.71	6.20	6.47	23.50	4.75
<i>Hydroides pseudouncinatus</i>			0.20	0.11			0.60	0.63	1.00	0.20
<i>Hydroides uncinata</i>			0.20	0.11			0.20	0.21	0.50	0.10
<i>Pomatoceros triqueter</i>	25.00	38.11	2.80	1.59	0.40	0.69	0.20	0.21	35.50	7.18
<i>Serpula concharum</i>			0.60	0.34			0.20	0.21	1.00	0.20
<i>Serpula vermicularis</i>	0.40	0.61	20.80	11.79	29.40	51.04	13.00	13.57	79.50	16.08
<i>Spirobranchus polytrema</i>	6.20	9.45							7.75	1.57
Number of species	29		28		24		23		42	
Number of individuals (N')	882		479		328		288		1 977	
Shannon Index (H')	2.885		3.141		2.617		3.54		3.946	
Equitability Index (J')	0.517		0.562		0.469		0.634		0.707	

Table II. Polychaetes of the *M. galloprovincialis* assemblage in the bay of Thessaloniki from the total number of samples at Neoi Epivates sampling site. Number of individuals (N'), Mean abundance (Am), Partial mean dominance (Dmp), Shannon index (H') and Equitability index (J').

<i>Polychaetofauna</i>	Winter 94		Summer 94		Winter 95		Summer 95		Total	
	Am	Dmp	Am	Dmp	Am	Dmp	Am	Dmp	Am	Dmp
<i>Harmothoe impar</i>	1.80	0.52	0.25	0.04	0.8	0.7	0.60	0.18	4.25	0.26
<i>Harmothoe reticulata</i>	1.00	0.29	29.75	4.75			2.40	0.71	34.00	2.09
<i>Harmothoe spinifera</i>	1.80	0.52	0.75	0.12	7.00	6.12	4.40	1.30	17.25	1.06
<i>Eumida sanguinea</i>	1.00	0.29	0.75	0.12	0.40	0.35	4.40	1.30	8.00	0.49
<i>Phyllodoce rubiginosa</i>	3.00	0.87	2.50	0.40	1.80	1.57	0.80	0.24	9.50	0.58
<i>Kefersteimia cirrata</i>			26.00	4.16	8.20	7.17	16.40	4.83	56.75	3.49
<i>Ophiodromus pallidus</i>	3.60	1.04	9.25	1.48					13.75	0.85
<i>Syllidia armata</i>	24.20	6.99	112.50	17.98	4.60	4.02	11.60	3.42	163.00	10.04
<i>Autolytus prolifer</i>	0.40	0.12			0.40	0.35	1.20	0.35	2.50	0.15
<i>Exogone naidina</i>	43.20	12.48	31.75	5.07	5.40	4.72	0.20	0.06	92.75	5.71
<i>Syllis krohnii</i>			0.75	0.12					0.75	0.05
<i>Syllis prolifera</i>	0.40	0.12	0.25	0.04					0.75	0.05
<i>Ceratonereis costae</i>	8.40	2.43	6.25	1.00	3.20	2.80	5.60	1.65	27.75	1.71
<i>Neanthes caudata</i>					0.20	0.17			0.25	0.02
<i>Nereis zonata</i>	0.40	0.12	5.25	0.84	2.60	2.27	0.80	0.24	10.00	0.62
<i>Perinereis cultrifera</i>							0.20	0.06	0.25	0.02
<i>Platynereis dumerilii</i>			0.50	0.08	0.60	0.52	1.00	0.29	2.50	0.15
<i>Lumbrineris coccinea</i>	1.60	0.46			0.60	0.52	1.00	0.29	4.00	0.25
<i>Lumbrineris funchalensis</i>	0.20	0.06					0.20	0.06	0.50	0.03
<i>Lysidice ninetta</i>	0.20	0.06	1.25	0.20			0.20	0.06	1.75	0.11
<i>Marphysa fallax</i>	0.40	0.12	0.50	0.08					1.00	0.06
<i>Nematonereis unicornis</i>	0.40	0.12	0.75	0.12	0.60	0.52	1.00	0.29	3.25	0.20
<i>Schistomeringos rudolphii</i>	3.80	1.10	34.00	5.43	10.00	8.74	61.80	18.22	128.50	7.91
<i>Polydora caeca</i>	33.60	9.71			0.60	0.52			42.75	2.63
<i>Polydora ciliata</i>	1.20	0.35			0.60	0.52			2.25	0.14
<i>Prionospio steenstrupi</i>	4.40	1.27	128.00	20.46	30.00	26.22	98.20	28.95	293.75	18.09
<i>Cirratulus</i> sp.	27.40	7.91	90.00	14.38	21.60	18.88	7.40	2.18	160.50	9.88
<i>Chaetozone setosa</i>	3.40	0.98							4.25	0.26
<i>Polyopthalmus pictus</i>	2.00	0.58	1.50	0.24	2.60	2.27	6.20	1.83	15.00	0.92
<i>Capitella capitata</i>					0.20	0.17			0.25	0.02
<i>Capitella giardi</i>	0.20	0.06							0.25	0.02
<i>Heteromastus filiformis</i>					0.40	0.35	24.80	7.31	31.50	1.94
<i>Sabellaria spinulosa</i>	44.40	12.82	0.25	0.04	0.40	0.35			56.25	3.46
<i>Amphitrite variabilis</i>	0.20	0.06	3.00	0.48	1.40	1.22	0.20	0.06	5.25	0.32
<i>Terebella lapidaria</i>	0.60	0.17	3.25	0.52	2.40	2.10	2.60	0.77	10.25	0.63
<i>Pseudopotamilla reniformis</i>					0.20	0.17	0.20	0.06	0.50	0.03
<i>Hydroides dianthus</i>	1.40	0.40							1.75	0.11
<i>Hydroides elegans</i>	23.00	6.64	7.00	1.12	2.20	1.92	33.40	9.85	80.25	4.94
<i>Hydroides pseudouncinatus</i>			8.25	1.32	0.20	0.17			8.50	0.52
<i>Pomatoceros triquetter</i>	21.40	6.18	5.25	0.84	3.00	2.62	0.20	0.06	36.00	2.22
<i>Serpula concharum</i>			0.50	0.08	0.40	0.35			1.00	0.06
<i>Serpula vermicularis</i>	80.20	23.17	115.50	18.46	1.80	1.57	52.20	15.39	281.75	17.35
<i>Spirobranchus polytrema</i>	7.00	2.02	0.25	0.04					9.00	0.55
Number of species	30		28		32		31		43	
Number of individuals (N')	2 503		1 696		1 731		572		6 502	
Shannon Index (H')	3.586		2.063		0.331		3.16		3.867	
Equitability Index (J')	0.642		0.369		0.059		0.566		0.692	

Table III. Polychaetes of the *M. galloprovincialis* assemblage in the bay of Thessaloniki from the total number of samples at Agia Triada sampling site. Number of individuals (N'), Mean abundance (Am), Partial mean dominance (Dmp), Shannon index (H') and Equitability index (J').

<i>Polychaetofauna</i>	Winter 94		Summer 94		Winter 95		Summer 95		Total	
	Am	Dmp	Am	Dmp	Am	Dmp	Am	Dmp	Am	Dmp
<i>Harmothoe areolata</i>	0.20	0.14	0.25	0.11			0.80	0.93	1.5	0.28
<i>Harmothoe impar</i>	4.60	3.23	1.50	0.65	0.25	2.50	0.40	0.46	8.00	1.51
<i>Harmothoe reticulata</i>			2.00	0.86			0.20	0.23	2.25	0.43
<i>Harmothoe spinifera</i>	1.60	1.12					0.60	0.69	2.75	0.52
<i>Eumida sanguinea</i>	0.80	0.56					0.20	0.23	1.25	0.24
<i>Phyllodoce rubiginosa</i>	1.00	0.70	2.75	1.18	0.50	5.00	1.40	1.62	6.25	1.18
<i>Kefersteinia cirrata</i>							12.00	13.89	15.00	2.84
<i>Ophiodromus pallidus</i>	1.40	0.98	5.00	2.15			7.80	9.03	16.50	3.12
<i>Syllidia armata</i>	2.80	1.96			0.50	5.00			4.00	0.76
<i>Autolytus prolifer</i>					0.25	2.50			0.25	0.05
<i>Exogone naidina</i>	2.00	1.40	2.00	0.86			2.20	2.55	7.25	1.37
<i>Syllis prolifera</i>			1.00	0.43	0.25	2.50			1.25	0.24
<i>Ceratonereis costae</i>	0.80	0.56			0.25	2.50	0.60	0.69	2.00	0.38
<i>Nereis zonata</i>							2.00	2.31	2.50	0.47
<i>Perinereis cultrifera</i>			0.50	0.22			1.00	1.16	1.75	0.33
<i>Platynereis dumerilii</i>							0.20	0.23	0.25	0.05
<i>Lumbrineris coccinea</i>	2.40	1.68			0.25	2.50	5.00	5.79	9.50	1.80
<i>Lumbrineris funchalensis</i>			0.75	0.32					0.75	0.14
<i>Lysidice ninetta</i>	0.20	0.14	4.00	1.72	0.25	2.50	1.00	1.16	5.75	1.09
<i>Marphysa fallax</i>			0.25	0.11					0.25	0.05
<i>Marphysa sanguinea</i>			0.25	0.11					0.25	0.05
<i>Nematonereis unicornis</i>			0.25	0.11					0.25	0.05
<i>Schistomeringos rudolphii</i>	0.20	0.14	10.00	4.31	0.25	2.50	9.20	10.65	22.00	4.16
<i>Polydora caeca</i>	2.60	1.82	2.75	1.18			2.20	2.55	8.75	1.66
<i>Polydora ciliata</i>	0.20	0.14	1.00	0.43	0.25	2.50			1.50	0.28
<i>Prionospio steenstrupi</i>			92.00	39.61	0.25	2.50	6.40	7.41	100.25	18.97
<i>Cirratulus</i> sp.	1.80	1.26	6.00	2.58	0.25	2.50	2.00	2.31	11.00	2.08
<i>Caulleriella alata</i>							0.20	0.23	0.25	0.05
<i>Polyopthalmus pictus</i>	0.20	0.14							0.25	0.05
<i>Capitella capitata</i>							2.60	3.01	3.25	0.61
<i>Capitella giardi</i>			2.50	1.08					2.50	0.47
<i>Heteromastus filiformis</i>			0.25	0.11			1.00	1.16	1.50	0.28
<i>Sabellaria spinulosa</i>	4.80	3.37	2.00	0.86					8.00	1.51
<i>Amphitrite variabilis</i>	0.80	0.56	1.25	0.54			1.00	1.16	3.50	0.66
<i>Terebella lapidaria</i>	1.00	0.70	3.25	1.40			2.00	2.31	7.00	1.32
<i>Pseudopotamilla reniformis</i>			0.75	0.32	0.25	2.50	0.40	0.46	1.50	0.28
<i>Hydroides elegans</i>	4.40	3.09			1.00	10.00			6.50	1.23
<i>Hydroides pseudouncinatus</i>	2.80	1.96	9.00	3.88	1.75	17.50	19.00	21.99	38.00	7.19
<i>Pomatoceros triqueter</i>	14.80	10.38							18.50	3.50
<i>Serpula concharum</i>	4.40	3.09	13.00	5.60					18.50	3.50
<i>Serpula vermicularis</i>	7.60	5.33	67.25	28.96	2.75	27.50	5.00	5.79	85.75	16.23
<i>Spirobranchus polytrema</i>	79.20	55.54	0.75	0.32	0.75	7.5			100.50	19.02
Number of species	25		28		17		26		42	
Number of individuals (N')	713		929		40		432		2 114	
Shannon Index (H')	2.678		2.809		3.459		3.795		3.871	
Equitability Index (J')	0.479		0.503		0.619		0.679		0.693	

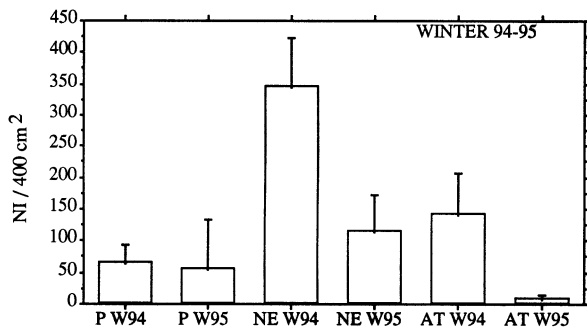


Figure 3. Fluctuation of the mean abundance of the Polychaetofauna during the winter months of 1994 and 1995, at the three sampling sites.

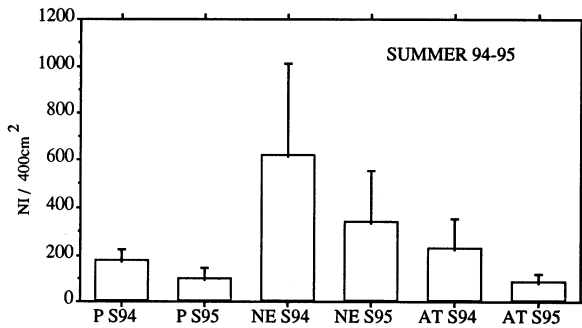


Figure 4. Fluctuation of the mean abundance of the Polychaetofauna during the summer months of 1994 and 1995, at the three sampling sites.

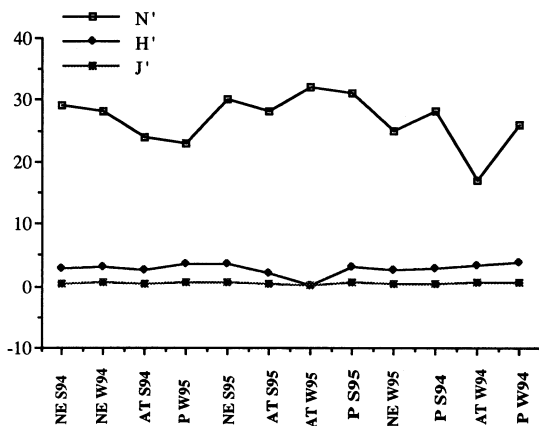


Figure 5. Number of Polychaetes species, Shannon index (H') and Equitability index (J') for each season and sampling site.

PE.95, PE.94/NE.95, PE.94/AT.94 and NE.95/AT.94, which do not show any significant difference (figure 3). The same test was employed for the summer samples and gave similar results (figure 4): 10 pairs of the 15 tested samples showed significant differences (Fisher

PLSD, 0.3), whereas the other 5 are homogeneous (PE.94/NE.95, PE.94/AT.94, PE.95/AT.95, NE.94/NE.95 and NE.95/AT.94).

3.3.2. Diversity

The total number of Polychaete species found does not differ significantly from one sampling site to another. Forty-two species were found in Peraia, 43 in Neoi Epivates and 42 in Agia Triada. Likewise, the values of Shannon Index (H'), as well as those of the equitability index (J') do not vary considerably among the three sampling sites (figure 5). The only significant variations are discovered in Agia Triada between the samples of winter 1995 and summer 1995. Nevertheless, the evenness factor, which varies around a value of 1, indicates that the Polychaetofauna of the assemblage shows stability, with no significant fluctuations in space and in time, and also that there are species with similar presence in the assemblage. It should also be mentioned that the diversity index varies between values 2.5 and 3, which corresponds with those of other related studies [23, 31].

3.4. Relationships between the Polychaetofauna and the structure of the musselbeds

According to Tsuchiya and Nishihira [36], the morphology and relative age of the mussels in an assemblage can play a significant role in the composition of the organisms that settle there. The older the mussels are in an assemblage, the larger is the number of the epifauna on the shells, since there are far more available habitats for settling. Therefore, the correlation between the abundance and the biomass of the mussels and the abundance and number of species of Polychaetes was examined so that the degree of interdependence of these parameters could be estimated.

The results showed that the abundance of the Polychaetofauna is not correlated with the abundance of the mussels or with their biomass ($r_s = 0.3$ $P = 0.07$, $r_s = 0.3$ $P = 0.06$ respectively). In contrast, the number of species is related to the mussels' biomass and to their abundance ($r_s = 0.4$ $p = 0.02$, $r_s = -0.4$ $P = 0.04$, respectively).

3.5. Affinity of the sampling sites

A study of the affinity of the samples based on the abundance of the populations of the Polychaetes

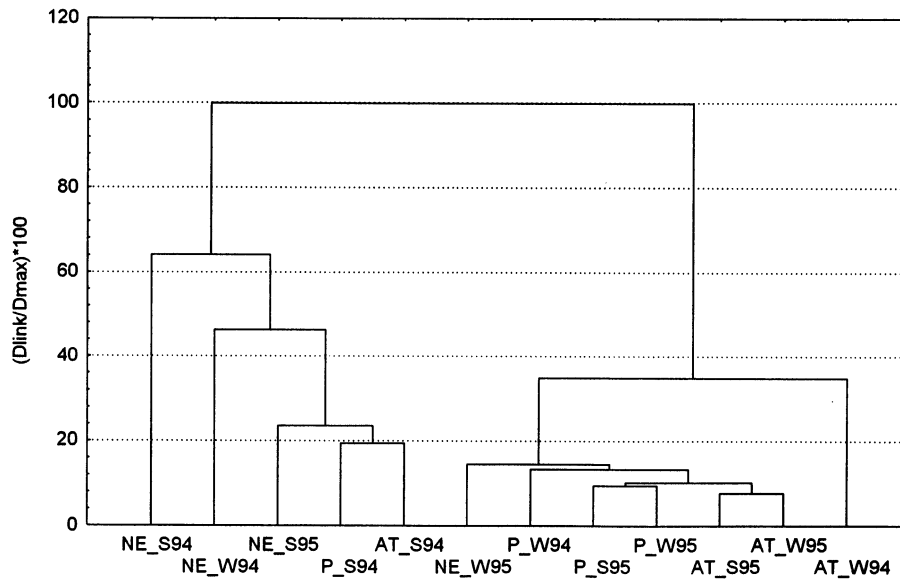


Figure 6. Dendrogramme (Euclidian distances, Ward’s method) of the abundance of samples, presenting the seasonal affinity of the samples in the years 1994 and 1995.

showed that the samples are divided into two basic groups, which in general correspond to the two seasons (*figure 6*). Some of the samples, though, do not follow this pattern. The 1994 winter samples from Neoi Epivates are grouped together with the summer samples, whereas the 1995 summer samples from Peraia and Agia Triada are placed among the winter samples. As *figure 7* and also the Anova test for the comparison of the abundance of the samples show, the 1994 winter samples of Neoi Epivates do not differ significantly from the rest of the summer samples, with the exception of the, likewise misplaced, 1995 summer samples of Peraia and Agia Triada. Similarly, the latter do not differ significantly from the rest of the winter samples.

With respect to the differentiations of the unevenness degree between samples of the same season, it was found to be higher in the summer samples than in winter samples. The degree of unevenness in the summer samples lies between 10 and 35 %, while in the winter samples between 20 and 65 %.

3.6. Distribution of the Polychaetes’ feeding guilds

The total number of species are grouped into nine feeding guilds:

- CMJ: carnivores, motile, with jawed pharynx;
- CMX: carnivores, motile, without jawed pharynx;
- HMJ: herbivores, motile, jawed;
- BMJ: burrowers, motile, jawed;
- FDT: filter-feeders, discretely motile, with tentacles;
- SdT: surface deposit-feeders, discretely motile, tentaculate;
- SST: surface deposit-feeders, sessile, tentaculate;
- BMX: burrowers, motile, without jawed pharynx and
- FST: filter-feeders, sessile, tentaculate.

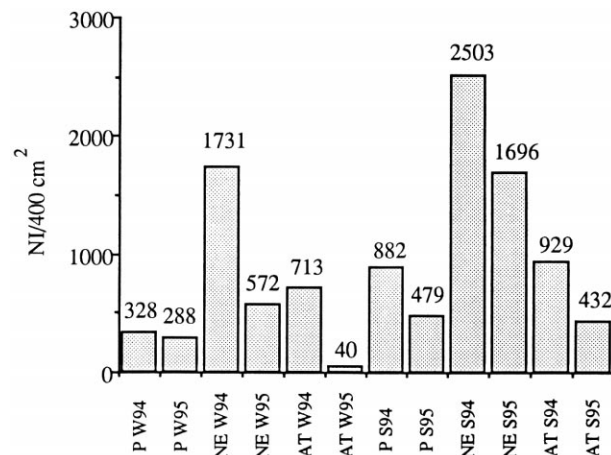


Figure 7. Abundance of the Polychaetofauna in space and in time.

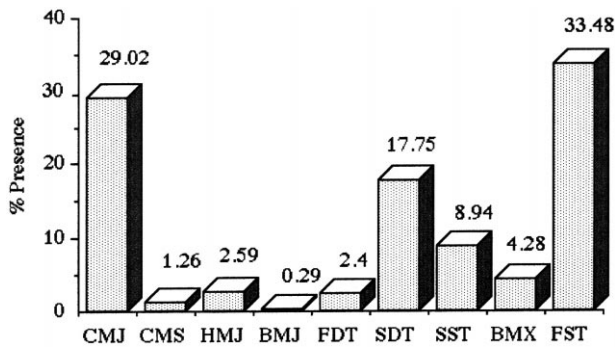


Figure 8. Mean dominance of the feeding guilds of the Polychaetes in the *M. galloprovincialis* assemblage in the bay of Thessaloniki.

Three of them are the most frequently observed in the assemblage (figure 8):

1. FST, reaching a percentage of 33.5%, to which the families Sabellariidae, Sabellidae and Serpulidae belong;
2. CMJ, which is represented by the families Polynoidae, Phyllodocidae, Hesionidae, Syllidae, Dorvilleidae and Lumbrineridae, with a percentage of 29%;
3. SDT which, in these samples, is exclusively represented by the species *Prionospio* (*Prionospio*) *steenstrupi* of Spionidae family, with a percentage of 17.8%.

This classification of the Polychaetes according to the type and size of their food and their locomotory pattern shows that the abundance of the microphagous Polychaetes is considerably higher than that of the macrophagous ones, with a percentage of 67.1% and 32.9% respectively. The major part of the macrophagous (92.1%) are carnivores, whereas the herbivores are represented in much smaller numbers (8%).

The locomotory patterns of the Polychaetes are directly affected by their feeding habits. In this study the sessile microphagous Polychaetes were the most abundant (42.4%), while the motile macrophagous were represented with a percentage of 37.4% and the surface deposit-feeders, discretely motile with 20.1%. The latter, however, were preclusively represented by only one species of Spionids.

The abundance of the motile and carnivore Polychaetes is significantly low (figure 8), due to biotic interactivities (e.g. predation) between the organisms

in the assemblage. For example, the presence of certain predators, such as the Crustacean decapods *Pilumnus hirtellus*, *Pisidia longirostris* and *Pachygrapsus marmoratus*, which appear quite frequently in the assemblage are able to consume large numbers of these Polychaetes (Damianidis and Chintiroglou, 1998). The herbivores, on the other hand, show only a small abundance, as expected in such assemblages where the growth of flora is very limited.

The examination of the degree of affinity between the samples regarding the abundance and composition of the feeding guilds of the Polychaetofauna led to the formation of two primary groups of samples (figure 9). The first group includes the summer samples of 1994 and 1995 and the winter samples of 1994 from Neoi Epivates, while the second group includes the rest of the samples. The differentiation level between the two groups does not exceed 25%, which confirms the stable composition of the feeding guilds of the Polychaetofauna of the assemblage in space and in time. The formation of the first group from exclusively Neoi Epivates samples can be attributed to the notably high abundance of the Polychaetofauna (1953, 2503 and 1696 individuals) in those samples. The comparison of the abundance of the feeding guilds of these samples (NE. S94, NE. S95 and NE. W94) with all the rest revealed a significant difference ($< P = 0.001$) and confirmed this assumption.

4. CONCLUSIONS

The study of the Polychaetofauna of the assemblage of *Mytilus galloprovincialis* in the Bay of Thessaloniki led to the identification of 48 species of Polychaetes, which belong to 16 families. Twenty-seven of these species were characterized as very common, 10 as common and 11 as rare. In particular, the composition of the Polychaetofauna of the musselbeds showed similar diversity indices to those from other areas in the Mediterranean Sea. When compared to them, however, the number of species identified in the Bay of Thessaloniki (48) is much higher. A review of the relevant literature revealed that the number of species and other factors that refer to the biodiversity of the *M. galloprovincialis* assemblages in the Bay of

Thessaloniki show some differentiations from the respective facts that other studies revealed in adjacent or other sites in the Mediterranean Sea. According to Kocatas [23], 35 species of Polychaetes were found in musselbeds in the Bay of Ismir, while Bellan-Santini [5] reported 14 species in clear water and 13 species in musselbeds of polluted waters. Saldanha [31] identified 33 species in various sites off Portugal's coastline, while Tsuchiya and Bellan-Santini [37] reported 33 in the region of Marseilles. Quite recently Topaloglou [35] mentioned only 10 species on musselbeds in the Bosphorus Channel. Consequently, this review indicates that the diversity of the Polychaetofauna of the musselbeds of artificial hard substrate on the eastern coasts of the Bay of Thessaloniki is very rich and so the structure of the assemblage is considered as good.

Further examination of the literature leads to some interesting conclusions. Many of the common species that were found by Kocatas [23] in Izmir Gulf were also frequently found in Thermaikos Gulf (*Schistomeringos rudolphii*, *Hydroides elegans*, *Terebella lapidaria* and *Audinia tentaculata*). Bellan-Santini [5] identified 25 species in corresponding mussel beds of the Gulf of Marseilles. Two of the most frequent (which were *Syllis prolifera*, *Platynereis dumerilii*, *Perinereis cultrifera* and *Spirobranchus polytrema*) be-

long to the very common species of this study, while the other two belong to the common ones. Finally, in Saldanha's study [31] the species *Lepidonotus clava*, *Eulalia viridis*, *Pomatoceros lamarckii*, *Syllis krohnii*, *Platynereis dumerilii* and *Lumbriconereis funchalensis* are reported as very common. Only the last three are identified in our study (*P. dumerilii* and *L. funchalensis* as very common species, and *S. krohnii* as rare). These differences with the samples examined by Saldanha [31], though from similar assemblages, should be put down to the fact that the samples originated from an entirely different geographical region (Portugal's coasts). Eventually, it should also be noted that a comparison with the results of other studies [21, 35, 37, 38] revealed no significant difference in the composition of the dominant species; this fact implies that the structure of the Polychaetofauna in the *M. galloprovincialis* assemblages in the Mediterranean Sea is homogeneous.

The study of the composition of the feeding guilds of the Polychaetes in the assemblage showed that the microphagous, sessile polychaetes are the most abundant. The carnivores predominate among the macrophagous. The particular composition of the feeding guilds covers most of the trophic levels required for the good function of an assemblage, so that the studied assemblage can be considered as well

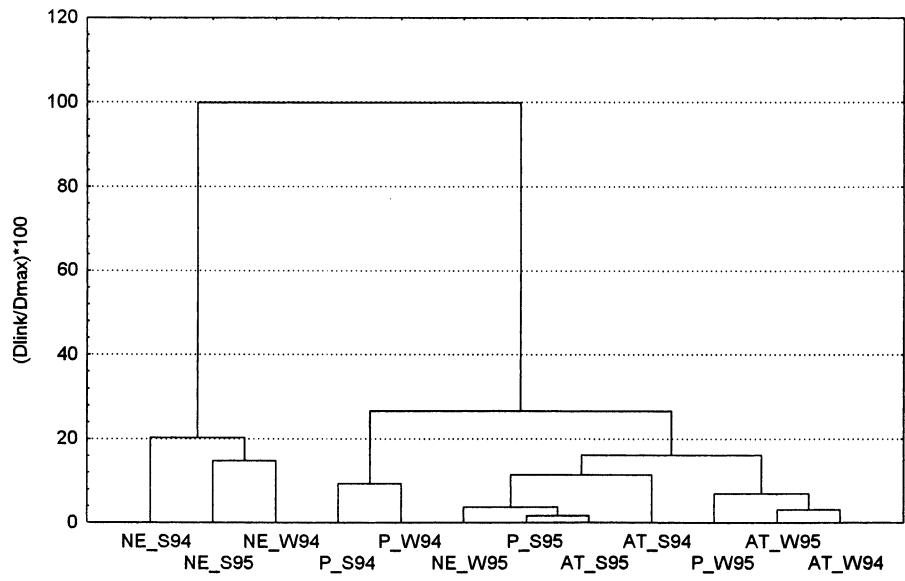


Figure 9. Dendrogramme (Euclidian distances, Ward's method) of the abundance of the feeding guilds of the Polychaetes in the samples, presenting their seasonal affinity in the years 1994 and 1995.

organized [16]. The dominance of the sessile/microphagous Polychaetes in the *M. galloprovincialis* assemblage can be considered as predictable, since all preconditions for their growth are fulfilled in this assemblage. Thus, the bivalves' shells offer an ideal surface for the settlement of the Polychaete larvae. The predominance of such species (e.g. Serpulids) is also favoured by the various patterns of reproduction that they employ (sexual, asexual, hermaphroditism), in combination with their long life cycle (6 to 8 years) [8, 18]. Moreover, the locality of the sampling sites can guarantee the continuous service of their energy needs through suspension feeding. As recent studies report [2] the circulation of water masses in the Thermaikos Gulf, as formed under the influence of the local winds and upwelling currents, is responsible for an increase of the amount of organic and inorganic material in the water at the sampling sites. As a result, the growth of the suspension feeding Polychaetes and the filter-feeding bivalves as well can be secured with constant provision of food particles.

The proportions of the different feeding guilds found in the *M. galloprovincialis* assemblage is different to that of other benthic assemblages. Bianchi and Morri [9] noted that in the coastal dendritic assemblages detritivorous Polychaetes (i.e. Spionidae) constituted 18% of the total species and filter-feeders 10%, whereas macrophagous (carnivores) exceeded 62%. In photophylic algae assemblages the macrophagous are predominant as well (46%), while the presence of discretely motile and microphagous Polychaetes is relatively limited (17% and 19% respectively) (Bianchi and Morri, 1985). It is remarkable that the *M. galloprovincialis* assemblage does not follow the same pattern, even though it is actually a part of the photophylic algae assemblage. This particularity indicates that the surrounding assemblages do not influence the *M. galloprovincialis* assemblage, at least at the Polychaetes feeding guilds level.

The facts presented in this study seem to be in accordance with those reported by Chintiroglou [11] about the composition of the feeding guilds of the Polychaetes associated with the coral *Cladocora caespitosa*. In these assemblages the sessile, filter-feeding Polychaetes outnumber all other types of feeding guilds. In this case, the Polychaetofauna is influenced by multiple biotic parameters, such as the chemical

barriers that prevent other organisms from settling. Although the two assemblages (*Cladocora/Mytilus*) significantly differ from each other on the grounds of ecology, biology and morphology, they show a certain similarity as far as the composition of the Polychaetes feeding guilds is concerned. This must be attributed to the substrate type (the hard substrate of coral colonies and mussel shells) that both assemblages offer for the settlement of the sessile and filter-feeding Polychaetes.

The structure of the musselbeds (biomass and number of mussels) influences the diversity of the Polychaetofauna significantly. This is the result of various biotic interactions between the organisms of the assemblage. These biotic interactions in the musselbeds are the cause of multiple differentiations and, therefore, should be taken into consideration in any study of these assemblages. These results are a clear indication that a large number of mussels enable the settlement of a relatively larger number of species of Polychaetes, as the number of habitats created among the mussels increases in proportion. This increased number of species may lead to interspecific interactions, which will subsequently limit the growth rate of their populations. On the other hand, when the size, the biomass of the mussels increases, it is very possible for larger organisms to settle there. This may have a negative impact on the abundance of the Polychaetes populations, due to predation by larger carnivorous and omnivorous organisms (e.g., sea anemones, decapods, ascidians, fish). Therefore, it seems that the diversity of the Polychaetofauna is influenced by the structure of mussel populations. The research conducted by Tsuchiya and Nishihira [36] on *M. edulis* populations in the Pacific Ocean, concluded similar results, as regards the relationships that develop between the age of the mussels and the diversity of the organisms settled on the musselbeds. However, the authors did not examine more specific biotic interactions (predation, territoriality, etc.), which also develop and affect, in a negative or positive way, these organisms which settle on the lower levels of the trophic web of the musselbeds. The above observations suggest that such relationships should be taken into consideration in any kind of research that deals with the structure and function of assemblages, especially in the case of hard substrate assemblages.

In general, the abundance of the Polychaetes is unequally distributed in space and in time. Even though it is difficult to give a clear explanation of these differentiations, they should be attributed to biotic interactions between the Polychaetofauna and the musselbeds in their structure. As mentioned before, an increase in the abundance of mussels affects the diversity of the Polychaetofauna positively, whereas an increase in the biomass has the opposite effect. In conclusion, the fact that the samples are divided into two groups (winter–summer) indicates that the abundance of the Polychaetes of the assemblage follows, in general, the succession of the seasons, with certain differentiations, which should be examined on a basis of biotic interactions.

Finally, according to Bellan [4], several of the Polychaetes species in this assemblage are sensitive to pollution (e.g. *Schistomeringos rudolphii*). This fact implies that the biomonitoring of this assemblage can lead to useful conclusions on the extension of pollution in the Bay of Thessaloniki [40]. Though the three sampling sites are located far from the industrial zone of Thessaloniki in the northwest of the bay (figure 1), they have become a tank for the sewage from the nearby fast-developing urban area. Therefore, the waters there are characterized as belonging to an intermediate level of pollution [29]. A biomonitoring programme, that will cover the Bay to its full extent, is required in order to determine whether the condition worsens or not. The facts presented in this study, along with those from the rest of the studies from the same programme, can play a basic role in such an attempt.

Acknowledgements

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