ORIGINAL ARTICLE

Chariton-Charles Chintiroglou ·
Panagiotis Damianidis · Chryssanthi Antoniadou ·
Marina Lantzouni · Dimitris Vafidis

Macrofauna biodiversity of mussel bed assemblages in Thermaikos Gulf (northern Aegean Sea)

Abstract Biomonitoring of mussel bed assemblages can provide valuable information about the impact of pollution on hard substrate assemblages. This study of *Mytilus galloprovincialis* mussel beds in Thermaikos Gulf (northern Aegean Sea) deals with the spatial and temporal structure of the associated fauna. Samples were collected and abiotic factors were measured in two successive years. Common biocoenotic methods were employed to analyze the data. The samples could be separated into three groups, with summer and winter samples being clearly different. A total of 100 species were found: polychaetes and crustaceans were the most dominant taxa. The assemblage shows high diversity with respect to species abundance. Biotic interactions within the assemblage appear to influence its composition, although the total evenness remains unaffected in space and time. The *M. galloprovincialis* assemblages can be found in clean as well as in polluted waters and, therefore, are of great interest in biomonitoring studies.

Keywords Infralittoral · Hard substratum · Mussel beds · Biomonitoring

Introduction

Mussel bed (*Mytilus galloprovincialis* LMK) assemblages can develop in clean and moderately polluted as well as polluted waters (e.g. Bellan-Santini et al. 1994; Damian-

Communicated by H.-D. Franke

C.-C. Chintiroglou (✉) · P. Damianidis · C. Antoniadou ·
M. Lantzouni
Department of Zoology, School of Biology,
Aristotle University of Thessaloniki,
Box 134, 54006 Thessaloniki, Greece
e-mail: chintigl@bio.auth.gr
Fax: +30-2310-998269

D. Vafidis
Fisheries Research Institute of Kavala,
Nea Peramos, 64007 Kavala, Greece

idis and Chintiroglou 2000). Therefore, biomonitoring of these assemblages can provide valuable information about the impact of pollution on hard bottom communities (e.g. Wenner 1988).

There is adequate information about the structure of *M. galloprovincialis* assemblages from various regions in the Mediterranean Sea, especially from the western Mediterranean coasts (Bellan 1969, 1980; Bellan-Santini 1969, 1981; Desrosiers et al. 1982, 1986; Hong 1983; Tursi et al. 1984; Tsuchiya and Bellan-Santini 1989), while information on the Aegean Sea is relatively limited (Kocatas 1978; Topaloglou and Kihara 1993; Lantzouni et al. 1998; Damianidis and Chintiroglou 2000). Many authors have put emphasis on the importance of these assemblages in biomonitoring studies (see Thiel and Ullrich 2002). Damianidis and Chintiroglou (2000) reported that the abiotic factors at all sampling sites within Thermaikos Gulf do not fluctuate in time. Therefore, any variation in the composition of *M. galloprovincialis* assemblages has to be attributed to biotic factors.

This study aims at the investigation of the spatial and temporal structure of the fauna associated with *M. galloprovincialis* assemblages on the eastern coast of Thermaikos gulf.

Methods

Study area

The sampling sites were selected on the basis of their historical background, as well as the exposure of the assemblages and the depth of their occurrence. Of all locations with artificial hard substrate along the east coast of Thessaloniki Bay, two appeared to be very similar in bathymetric distribution and exposure of *M. galloprovincialis* populations: the piers of Agia Triada (ST1) and Perea (ST2) (Fig. 1). These piers were constructed 25 years ago and are supported by concrete pillars, which comprise the substrate for the mussel beds. At these sampling sites, the *M. galloprovincialis* populations develop a uniform physiognomic aspect, with large numbers of mussels covering an area that extends from the lower infralittoral zone down to a depth of 2.5 m.
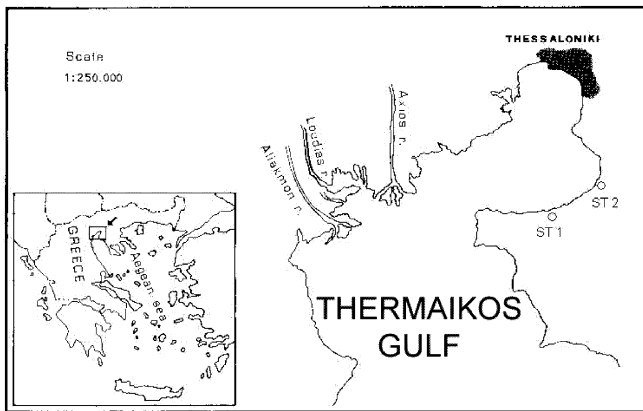
Fig. 1 Map showing Thermaikos Gulf and the two sampling sites (ST1, ST2)

Physico-chemical factors

During this study, physico-chemical factors such as salinity (S‰), conductivity (µS/cm), water clarity (m), dissolved oxygen (mg/l), temperature (°C) and total hydrodynamics were measured. All measurements were made using WTW (Wissenschaftlich-Technische Werkstaetten, Weilheim, Germany) and Lovibond Checkit (Dortmund, Germany) micro-electronic equipment and water clarity was examined using the Secchi disc. These measurements were conducted monthly at each sampling site and the results have already been reported by Damianidis and Chintiroglou (2000).

Sampling methods

Sampling was carried out while scuba diving. Samples were taken as described by Chintiroglou and Koukouras (1992). The area covered by the quadrat sampler was 400 cm^2 (Stirn 1981; Bakus 1990). Three replicates were taken each time. The samples, 24 in total, were collected during winter and summer of 1994 and 1995. After sampling, the specimens were preserved in 10% formalin and were transferred to the laboratory for further treatment. All samples were collected by the same scuba diver.

Data analysis

Common biocoenotic methods were employed to analyze the faunal composition of the *M. galloprovincialis* assemblages (Bellan-Santini 1981; Damianidis and Chintiroglou 2000). Hence, the numerical abundance (*N*) on a scale of 1 m^2, the mean dominance (*D*) and the frequency (*f*) were estimated. Also Shannon-Weaver's (*H'*), and Margalef (*d*) and Pielou's Evenness (*J'*) were calculated on a log$_2$ basis (Daget 1979).

Seasonal differences in the mean numbers of individuals were tested using one-way ANOVA and multiple comparisons. All data were then converted to logarithms. The Spearman rank correlation coefficient (*r*$_s$) was employed to determine the relation of the number of mussels (*Ab*$_M$) with faunal abundance (*mAb*) and richness (*R*).

The numerical abundance data, obtained per sampling station, were analyzed using cluster and multidimensional scaling (mds) techniques, based on the Bray-Curtis similarity, using the PRIMER package (see Clarke and Green 1988; Clarke and Warwick 1994). The square root transformation was applied in order to increase the contribution of the rare species (Clarke and Warwick 1994). The significance of the multivariate results was assessed using the ANOSIM test. SIMPER analysis was performed in order to identify the percentage contribution of each species to the overall similarity within a site and the dissimilarity among sites (Clarke 1993). The

above were carried out to examine the similarity degree of samples, in both space and time.

Results

Composition of the assemblage

A total of 100 species were found associated with *M. galloprovincialis* assemblages in Thermaikos gulf (Table 1). The distribution of these species in major taxonomic groups is given in Table 2. The dominant groups are polychaetes (37.5%) and crustaceans (30.9%). As shown in Table 1, 17 species were distinguished as "very common" (*f*≥50%), 26 as "rare" (*f*<10%), and 57 as "common" (10%<*f*<50%).

Among the very common species, the polyclad *Stylochus* sp. and the decapods *Pilumnus hirtelus* and *Pisidia longicornis* have been described as the main predators of mussels (see Galleni et al. 1977; Damianidis and Chintiroglou 2000). The cirripeds *Balanus perforatus* and *B. trigonus*, the polychaete *Serpula vermicularis* and Bryozoa sp1, are well-known as organisms that often settle on mussel shells (Bussani 1983; Damianidis and Chintiroglou 2000). The rest of the very common species are free motile organisms which employ various modes of feeding. The tube-building peracarids are detritivores (Barnard 1958, 1963; Isaac et al. 1994), *Ophiothrix* sp. (Pérès 1976) is a suspensivore, and the polychaete *Staurocephalus rudolphii* is a carnivore (Fauchald and Jumars 1979).

Relationships between fauna and structure of mussel beds

According to Tsuchiya and Nishihira (1986), the morphology and relative age of the mussels in an assemblage can play a significant role in the composition of the associated fauna. Therefore, the correlations of mussel abundance with species richness and faunal abundance, respectively, were examined.

For both summer and winter samples, faunal abundance (*mAb*) and richness (*R*) were not correlated (*P*>0.5) with the mussel abundance (*Ab*$_M$).

Diversity

A total of 17,090 individuals, representing 100 faunal species, were examined. As shown in Table 1, the number of species and the diversity indices (*H'*, *d* and *J'*), were determined for each sampling station and season (winter/summer). The number of species ranged from 37 to 49 in winter, and from 45 to 60 in summer. The diversity indices ranged proportionately as they appeared to be higher in the summer samples (Table 1).

Table 1 A list of species found in the *Mytilus galloprovincialis* assemblage at two stations in Thermaikos Gulf, in summer and winter of 1994 and 1995. *W* Winter, *S* summer, *f* frequency, *mAb* mean abundance, D_p partial mean dominance, *d* diversity index, *H'* Shannon Index, *J'* Equitability Index

Species	ST1 W94 f	mAb	D_p	ST2 W94 f	mAb	D_p	ST1 W95 f	mAb	D_p	ST2 W95 f	mAb	D_p	ST1 S94 f	mAb	D_p	ST2 S94 f	mAb	D_p	ST1 S95 f	mAb	D_p	ST2 S95 f	mAb	D_p	Total f	mAb	D_p
Eudendrium sp.	66			100									66						66			100			42		
Cereus pentuculatus													33	8	0.02										4	1	0.006
Podocoryna sp.																			33						4		
Leptoplana sp.	66	66	0.59	100	83	0.66				100	317	3.50	66	42	0.12	33	17	0.06		808	4.40				46	167	0.936
Stylochus sp.	66	33	0.30	33	8	0.07	33	8	0.11				100	308	0.87	100	183	0.69	66	167	0.91	100	892	4.09	62	200	1.123
Turbellaria sp1	66	91	0.81	33	17	0.13	100	83	1.11	66	125	1.38	33	33	0.09				33	100	0.54				41	56	0.316
Turbellaria sp2	33	83	0.74										33	17	0.05				66	142	0.77				17	30	0.170
Nemertina sp.1										33	8	0.09													4	1	0.006
Nematoda	33	325	2.89	66	25	0.20							100	342	0.97	66	458	1.73				33	108	0.50	37	157	0.884
Phascolosoma granulatum																						33	8	0.04	4	1	0.006
Amphitrite variabilis	33	8	0.07	33	33	0.27				66	25	0.28	100	150	0.42	33	17	0.06				33	17	0.08	37	31	0.176
Autolytus prolifer							33	8	0.11										66	33	0.18				12	5	0.029
Capitella capitata																			33	8	0.05	66	42	0.19	12	6	0.035
Capitellides giardi																33	33	0.13							4	4	0.023
Ceratonereis costae	33	8	0.07				33	8	0.11	66	33	0.37							33	8	0.05	66	17	0.08	29	9	0.053
Chaetozone setosa	100	58	0.52										33	25	0.07										17	10	0.059
Cirratulus sp.				100	50	0.40				33	75	0.83	66	67	0.19	66	125	0.47				66	75	0.34	41	49	0.275
Eulalia sanguinea				33	42	0.33				66	58	0.64				33	33	0.13	66	50	0.27	66	50	0.23	21	15	0.082
Exogone gemmifera	33	8	0.07	33	8	0.07										33	8	0.03							21	17	0.094
Harmothoe areolata				33	8	0.07										33	8	0.03							8	2	0.012
H. impar				66	75	0.60							100	75	0.21	66	25	0.09	33	8	0.05				25	15	0.082
H. reticulata	100	58	0.52	100	67	0.53	33	8	0.11				33	8	0.02	33	33	0.13	33	17	0.09				33	23	0.129
H. spinifera	100	367	3.26							33	17	0.18							33	58	0.32	66	17	0.08	46	67	0.374
Heterocirrus alatus																			33	25	0.14	33	8	0.04	8	4	0.023
Heteromastus filiformis													33	8	0.02	33	8	0.03	33	125	0.68	33	42	0.19	17	23	0.129
Hydroides elegans	33	8	0.07	33	50	0.40	33	33	0.44	66	325	3.59	33	42	0.12				66	142	0.77				33	75	0.421
H. pseudo-uncinata				66	108	0.86	33	17	0.22							66	175	0.66	33	25	0.14	66	633	2.91	33	120	0.673
Kefersteinia cirrata				33	58	0.46				33	42	0.46	33	50	0.14	66	92	0.35				66	100	0.46	29	43	0.240
Labrineris coccinea													33	8	0.02	66	25	0.09							12	4	0.023
L. funchalensis							33	8	0.11				66	17	0.12	66	17	0.06	100	33	0.18	33	17	0.08	37	15	0.082
Lysidice ninetta													33	8	0.03				33	8	0.05				8	2	0.012
Magalia perarmata	100	275	2.44				66	17	0.22	33	17	0.18	66	300	0.85										33	76	0.427
Marphysa fallax	33	8	0.07													33	8	0.03							12	3	0.018
M. sanguinea	33	8	0.07																33	17	0.09				8	3	0.018

Table 1 (continued)

Species	ST1 W94			ST2 W94			ST1 W95			ST2 W95			ST1 S94			ST2 S94			ST1 S95			ST2 S95			Total		
	f	mAb	D_p	f	mAb	D_p	f	mAb	D_p	f	mAb	D_p	f	mAb	D_p	f	mAb	D_p	f	mAb	D_p	f	mAb	D_p	f	mAb	D_p
Nematonereis unicornis	33												66	33	0.09				33	8	0.05				4	1	0.006
Nereis caudata		17	0.15							33	8	0.09										100	42	0.19	29	13	0.070
N. zonata										66	92	1.01										33	25	0.11	4	3	0.018
Ophiodromus pallidus													100	333	0.94				100	275	1.50	33	225	1.03	37	116	0.650
Perinereis cultrifera	33	8	0.07							33	8	0.09										33	8	0.04	12	3	0.018
Phyllodoce rubiginosa	66	25	0.22	100	42	0.33							66	50	0.14	33	17	0.06				100	33	0.15	46	21	0.117
Platynereis dumerilii	33	8	0.07	66	75	0.60				33	8	0.09	33	8	0.02							66	42	0.19	29	18	0.099
Polydora caeca	66	17	0.15	66	67	0.53	33	8	0.11	33	8	0.09				66	42	0.16	33	25	0.14	66	50	0.23	37	25	0.140
P. ciliata	66	33	0.30													33	17	0.06	100	83	0.45				33	19	0.105
Polyophthalmus pictus	33	8	0.07													33	17	0.06							8	3	0.018
Potamila reniformis																33	17	0.06							4	2	0.012
Potamoceros triqueter	100	283	2.52	33	33	0.27	33	8	0.11				100	42	0.12				33	8	0.05				33	46	0.257
Prionospio malmgrenii													100	2,108	5.97	100	1,625	6.12	33	142	0.77	100	208	0.96	46	511	2.873
Sabellaria spinulosa	66	25	0.22	33	150	1.20							33	25	0.07	33	33	0.13	33	17	0.09				25	31	0.176
Serpula concharum				33	158	1.26							33	25	0.07	33	433	1.63							12	77	0.433
S. vermicularis	33	17	0.15	100	150	1.20	66	92	1.22	66	1,125	12.43	100	508	1.44	66	1,575	5.93	100	283	1.54	100	200	0.92	79	494	2.774
Spirobranchus polytrema				100	2,483	19.79	33	8	0.11							33	8	0.03							21	313	1.775
Staurocephalus rudolphii	66	33	0.30	66	33	0.30	33	8	0.11				100	533	1.51	100	150	0.56	100	267	1.45	100	175	0.80	62	146	0.819
Syllis krohnii	33	8	0.07	33	8	0.07	33	8	0.11				66	17	0.05	66	33	0.13	33	8	0.05				25	8	0.047
S. prolifera													66	17	0.05	66	33	0.13	33	8	0.05				25	8	0.047
Terebella lapidaria				33	8	0.07				66	50	0.55				33	58	0.22	100	242	1.32	33	17	0.08	33	47	0.263
Cerithium repestre	33	8	0.07	33	8	0.07	33	8	0.11	33	8	0.09													12	3	0.018
Hanomia ephipium							100	100	1.33				33	8	0.02										4	1	0.006
Hiatella rugosa	66	50	0.44							33	8	0.09	33	8	0.02	66	208	0.78				33	8	0.04	25	34	0.193
Hexaplex trunculus													66	125	0.35	100	417	1.57	66	33	0.18	66	133	0.61	41	90	0.503
Hinia incrassata													33	17	0.05										4	2	0.012
Mytilus gallo-provincialis	100	5,142	45.7	100	4,475	35.66	100	2,300	30.60	100	2,233	24.68	100	8,375	23.7	100	10,408	39.18	100	5,108	27.83	100	5,742	26.36	100	5,473	30.743
Odostomia sp.				33	8	0.07	33	8	0.11																4	1	0.006
Aora sp.				33	8	0.07																			8	2	0.012
Amphithoe ramondi				33	8	0.07																			8	3	0.018
Athanas nitescens	33	17	0.15	66	125	1.00	66	50	0.67	33	8	0.09	100	1,233	3.49	66	250	0.94	100	200	1.09	100	258	1.19	79	295	1.656
Balanus eburneus																			33	17	0.09	33	8	0.04	21	16	0.088
B. perforatus	100	617	5.48	100	233	1.86	100	1,592	21.18	100	2,167	23.94	100	183	0.52	100	233	0.88	100	208	1.13	100	425	1.95	100	707	3.973
B. trigonus	66	167	1.48	100	1,383	11.02	100	775	10.31	100	217	2.39	100	1,092	3.09	100	717	2.70	100	2,600	14.16	100	917	4.21	96	983	5.524
Copepoda	100	117	1.04	66	100	0.80	33	8	0.11	33	33	0.37	100	125	0.35	33	58	0.22							46	55	0.310
Corophium acherusicum													100	592	1.67	33	8	0.03							17	75	0.421
C. acutum	33	8	0.07	66	17	0.13	66	50	0.67	66	33	0.37	66	308	0.87	66	42	0.16	66	83	0.45	100	33	0.15	54	69	0.386
C. sextonae							33	8	0.11	66	50	0.55	66	25	0.07										33	14	0.076
Corophium sp.										33	25	0.28	100	11,400	32.26	100	6,583	24.78	100	4,842	26.37	100	9,242	42.43	54	4,011	22.534
Erichthonius brasiliensis	66	42	0.33	66	42	0.33				33	8	0.09	33	17	0.05	66	100	0.38	66	42	0.23	100	75	0.34	46	35	0.199

Table 1 (continued)

Species	ST1 W94 f	ST1 W94 mAb	ST1 W94 D_p	ST2 W94 f	ST2 W94 mAb	ST2 W94 D_p	ST1 W95 f	ST1 W95 mAb	ST1 W95 D_p	ST2 W95 f	ST2 W95 mAb	ST2 W95 D_p	ST1 S94 f	ST1 S94 mAb	ST1 S94 D_p	ST2 S94 f	ST2 S94 mAb	ST2 S94 D_p	ST1 S95 f	ST1 S95 mAb	ST1 S95 D_p	ST2 S95 f	ST2 S95 mAb	ST2 S95 D_p	Total f	Total mAb	Total D_p
Diogenes pugilator							33	8	0.11																4	1	0.006
Elasmopus rapax	100	25	0.22	100	417	3.32	100	1,258	16.74	100	1,017	11.23													50	340	1.908
Euridice tuberculata	33	8	0.07				33	8	0.11																4	1	0.006
Jassa marmorata	100	100	0.89	100	192	1.53				33	92	1.01													33	49	0.275
Lembos webstri	66	50	0.44																						8	6	0.035
Leptochelya savignii	66	25	0.22	33	8	0.07							33	17	0.05										17	6	0.035
Maera inaequipes	100	33	0.30	100	450	3.59	100	283	3.77	33	75	0.83	66	117	0.33	100	100	0.38	100	383	2.09	100	400	1.84	87	230	1.293
Microdeutopus sp.										33	8	0.09	33	8	0.02				33	8	0.05				12	3	0.018
Pachygrapsus marmoratus														25	0.07	33	8	0.03	33	17	0.09	33	17	0.08	12	8	0.047
Parhyale aquilina	33	17	0.15																						4	2	0.012
Palaemon sp.							66	17	0.22	66	67	0.74													8	2	0.012
Pilumnus hirtelus	100	158	1.41	100	150	1.20	100	342	4.55	66	167	1.84	100	483	1.37	100	350	1.32	100	267	1.45	100	217	0.99	96	267	1.498
Pisidia longicornis	100	1,167	10.37	100	700	5.58	100	308	4.10	100	217	2.39	100	3,792	10.73	100	700	2.63	100	375	2.04	100	683	3.14	100	993	5.576
Sphaeroma serratum				33	8	0.07							33	8	0.02										4	1	0.006
Stenothoe cavimana				33	8	0.07	66	33	0.44	66	42	0.46													4	1	0.006
Tanais sp.				66	33	0.27	33	8	0.11	66	8	0.09	100	233	0.66	66	33	0.13	66	17	0.09	33	33	0.15	50	52	0.293
Thoralus cranchii	100	25	0.22	66	17	0.13	66	25	0.33	33	8	0.09	100	133	0.38	100	100	0.38	33	8	0.05				62	41	0.228
Unidentified Amphipoda																			66	67	0.36				17	14	0.076
Nymphon sp.				33	8	0.07							33	8	0.02				33	8	0.05				17	4	0.023
Proxichilidi-dae sp.																									12	4	0.023
Bryozoa sp.1							33			100						33			100			66			50		
Bryozoa sp.2																			33						4		
Ophiothrix sp.	100	1,375	12.22	100	358	2.86				66	192	2.12	100	1,675	4.74	100	917	3.45	100	900	4.90	100	517	2.37	83	742	4.166
Paracentrotus lividus	33	17	0.15	33	8	0.07							66	25	0.07							33	17	0.08	21	8	0.047
Styella plicata										33	17	0.18	33	67	0.19				33	33	0.18	33	8	0.04	17	16	0.088
Gobius sp.										33	8	0.09	33	8	0.02	33	8	0.03							12	3	0.018
No. indi-viduals	1,352			1,509			906			1,094			4,246			3,189			2,212			2,619			17,090		
No. species	49			46			37			44			60			51			54			45			100		
d	7.12			6.39			5.27			6.11			7.52			6.47			6.64			5.55			10.13		
Shannon Index (H')	3.94			3.74			3.1			3.54			3.29			3.44			3.46			2.77			4.11		
Equitability Index (J')																											

Table 2 Distribution of the species found in the assemblage to the level of major taxa

Taxa	Number of species	Percentage %
Polychaeta	45	37.5
Crustacea	31	30.39
Mollusca	9	8.82
Turbellaria	4	3.92
Cnidaria	3	2.94
Bryozoa	2	1.96
Echinodermata	2	1.96
Nemertina	1	0.98
Nematoda	1	0.98
Sipunculida	1	0.98
Pantopoda	1	0.98
Ascidiacea	1	0.98
Pisces	1	0.98
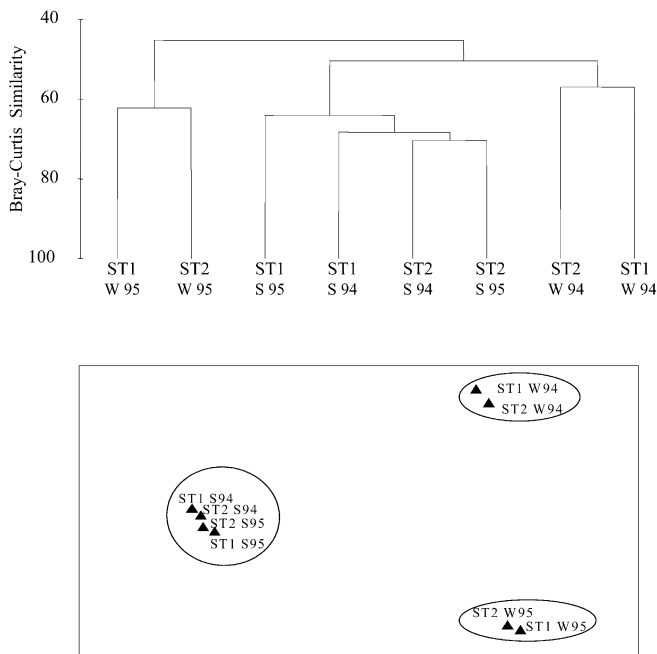
Fig. 2 Affinity of the sampling sites according to cluster and non-metric multidimensional sampling analyses

Abundance

The comparison of the faunal abundance in time (within and between years) and in space (sampling sites) was based on the examination of the null hypothesis that the abundance of the fauna does not differ significantly. One-way ANOVA was used to detect the exact differences and showed an equal distribution of the abundance of the fauna in winter as well as in summer samples ($F=0.58$, $df=1,3$, $P=0.64$ in winter samples, and $F=2.47$, $df=1,3$, $P=0.14$ in summer samples).

Affinity of sampling in space and time

The affinity of all sampling sites is given in Fig. 2. Both analyses (cluster and non-metric mds) indicate a separation of samples into three main groups at about 50% similarity level. The winter samples from 1995 form group A, the winter samples from 1994 group B and the summer samples from both years (1994 and 1995) group C. Summer and winter samples are separated, indicating seasonality of the benthic assemblages. The two stations were not separated. Samples from successive years were only separated in winter. The stress value for the two-dimensional mds configuration is 0.01, indicating an excellent ordination of samples (Clarke and Warwick 1994). The performance of a one-way ANOSIM test gave global $R=1$ at a significance level of $P<0.005$, so the separation of the three groups (A, B and C) was confirmed. Group A showed an average similarity of 62%. As identified by SIMPER analysis, five species (*M. galloprovincialis*, *B. perforatus*, *Elasmopus rapax*, *Pisidia longicornis* and *B. trigonus*) were responsible for 60% of the average similarity, and 15 species for 90%. Group B reached an average similarity of 57%, with seven species (*M. galloprovincialis*, *Pisidia longicornis*, *Ophiothrix fragilis*, *B. perforatus*, *B. trigonus*, *Pilumnus hirtelus* and *Athanas nitescens*) covering 60% of this similarity, and 22 species 90%. Finally, group C reached an average similarity of 67%, with eight species (*Corophium* sp., *M. galloprovincialis*, *B. trigonus*, *O. fragilis*, *Pisidia longicornis*, *Prionospio malmgreni*, *S. vermicularis* and *Pilumnus hirtelus*) being responsible for 60% of the similarity, and 26 species for 90%. As regards the divergence between groups, we found that group A had an average dissimilarity percentage of 50% with group B (21 species contributed 60% and 55 species 90% of this value) and 57% with group C (16 species contributed 60% and 54 species 90%), while the dissimilarity percentage between groups B and C was 50% (22 species contributed 60%, and 58 species 90%). It is quite clear that only a few species are important for characterizing the groups, while most of them are important for differentiating the groups.

Discussion

Photophilic soft algae communities probably have the highest faunal and flora diversity of all benthic bio-coenoses in the Mediterranean (Pérès 1982; Bellan-Santini et al. 1994). The assemblage of mussel beds of *M. galloprovincialis* in Thermaikos Gulf belongs to this type of biocoenosis, showing high diversity with respect to species abundance. One hundred animal species were recorded during this study, 17 of which were characterized as very common ($f \geq 50\%$), and 57 as common ($10\% < f < 50\%$). The recorded species have been reported by many authors as members of the assemblages of sublittoral photophilic algae (Bellan-Santini 1969; Saldanha 1974; Kocatas 1978; Bellan 1980; Hong 1983;

Table 3 Literature data on *M. galloprovincialis* assemblages. *Q* Quadrat, *C* core, *INFR* infralittoral, *MID* midlittoral, *P* polluted, *NP* non-polluted

Source	Location	Ecological zone	Sampling method	Surface (cm^2)	No. faunal species	No. poly chaete species	No. crustacean species	Pollution of biotope
Bellan-Santini (1969)	Marseilles	INFR	Q	400	43	13	14	P
Bellan (1969, 1980)	Marseilles	INFR	Q	400	98	25	24	NP
Kocatas (1978)	E Aegean Sea	INFR	Q	400	111	35	32	P
Bellan (1980)	NW Mediterranean Sea	INFR	Q	400		20/114.3		NP
Bellan (1980)	NW Mediterranean Sea	INFR	Q	400		20/78.2		P
Thiel and Ullrich (2002)	Chile	INFR	Q	100	62	15	14	NP
Svanne and Setyobudiandi (1996)	Denmark	INFR	C	282	43	13	10	NP
Lintas and Seed (1994)	N Wales	MID & INFR	Q	25	59	4	25	NP
Tiganus (1979)	Black Sea	INFR	Q	??	?22	?	?	?
Topaloglou and Kihara (1993)	Bosporus	INFR	Q	400	48	10	22	NP
D'Anna et al. (1985)	Sicily, Italy	INFR	Q	400	89	32	8	P & NP
Tsuchiya and Nishihira (1986)	N Japan	INFR	Q	100	69	27	17	NP
Tsuchiya and Bellan-Santini (1989)	Marseilles	INFR	Q	100	99	33	30	NP
Damianidis and Chintiroglou (2000)	Thermaikos Gulf	INFR	Q	400		48		NP
Saldanha (1974)	Portugal	INFR	Q	500	131	27	36	NP
Saldanha (1974)	Portugal	MID	Q	500	67	10	8	NP

Desrosiers et al. 1986; Marinopoulos 1988; Chintiroglou and Koukouras 1992; Topaloglou and Kihara 1993; Bellan-Santini et al. 1994; Lantzouni et al. 1998; Baxevanis and Chintiroglou 2000; Damianidis and Chintiroglou 2000).

The biodiversity of *M. galloprovincialis* assemblages in Thermaikos Gulf differs from those reported for other Mediterranean and northern European sites (Table 3). Most authors have used similar methods for the study of hard substrates (based mostly on work by Bellan-Santini 1969) (Table 3), yet data from different geographical areas are difficult to compare. The highest species abundance (*R*=131) was found in the infralittoral zone of the Portuguese coast. The clean waters of Marseilles, Ismir and Thermaikos Gulf also show high species abundance, while species abundance was relatively low in the Bosporus, on Danish coasts, in the midlittoral zone of the Portuguese coast and in the polluted waters of Marseilles. The respective values in Japan and Chile ranged around 65, while 89 species were counted in Italy and 56 in Aberffraw (N Wales).

Table 3 also shows that polychaetes and crustaceans are the most important taxonomic groups of the assemblage, contributing almost 50% of the total faunal species abundance. The abundance of these groups, however, varies from one area to another and also seems to be dependent on the specific features of each study area (polluted/non-polluted; midlittoral/supralittoral), a fact that was also reported by Thiel and Ullrich (2002). Saldanha (1974), for instance, recorded fewer polychaetes and more crustacean species on the coasts of Portugal, while D'Anna et al. (1985) recorded exactly the opposite for Sicily. Kocatas (1978) found 35 polychaete and 32 crustacean species in the Izmir Bay, whereas Topaloglou and Kihara (1993) reported 10 polychaete and 22 crustacean species for the Bosporus. Seed and Suchanek (1992) drew the same conclusions, even though the Mediterranean mussel assemblages were not the focus of their work. The total diversity of mussel assemblages in the studied areas shows no significant variations. Furthermore, significant similarities exist at the taxonomic level. It should also be noted that, according to Damianidis and Chintiroglou (2000), there is no significant difference in the composition of the dominant species: this implies that the structure of the polychaete fauna of *M. galloprovincialis* assemblages in the Mediterranean Sea is largely homogeneous.

An important part of the study of mussel assemblages is the study of interactions between the structure of mussel populations and the associated fauna (Tsuchiya and Nishihira 1986; Lintas and Seed 1994). These studies have produced contradictory results. According to Tsuchiya and Nishihira (1986), the structure of mussel beds in the Pacific Ocean (Japan) has a direct effect on the diversity of the assemblages. Lintas and Seed (1994) suggested that the fauna associated with *M. edulis* appear to be related largely to mussel density. Damianidis and Chintiroglou (2000) reported similar results on the polychaete fauna of mussel beds in Thermaikos Gulf. In the present study, however, no relationship was found between mussel density and the abundance and diversity of the assemblage. As regards the structure (= distribution

of size classes of the populations) of the *M. galloprovincialis* populations, there is certain information in Le Breton and Chintiroglou (1998) indicating an uneven distribution in space and time. Although information is still limited, it appears that biotic interactions have a strong effect on the composition of the assemblage, which seems to decrease when the assemblage is studied as a whole. In this case, the composition of the assemblages is largely even in space and time. Nevertheless, attention should be paid to any variations in order to understand the biotic interactions in hard substrate assemblages (see Damianidis and Chintiroglou 2000).

The evenness of the studied assemblage showed some variation in space, and particularly in time, while the total homogeny of the faunal composition remained unaffected. The separate analyses conducted by Lantzouni et al. (1998) and Damianidis and Chintiroglou (2000) produced similar results.

In conclusion, there is now adequate information about *M. galloprovincialis* assemblages, although there are still open questions. For biomonitoring of marine benthic assemblages, knowledge of the structure and function of *M. galloprovincialis* assemblages can play an important role. The main advantage of studying such assemblages, on a smaller or wider scale, is their similar physiognomic appearance (Reish 1971; Wenner 1988). As these assemblages can be found in clean as well as in polluted waters, they are of great interest in biomonitoring studies (see Wenner 1988).

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