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Benthic amphipod (Crustacea) fauna of the Bandırma and Erdek Gulfs and some environmental factors affecting their distribution

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This study aims to determine the environmental factors affecting the fauna and distribution of benthic amphipod species inhabiting in the Bandırma and Erdek Gulfs which are located on the south of the Marmara Sea. Total of 66 species belonging to 22 families were identified after analyzing the samples collected seasonally from the depths ranging between 1 and 30 m between 2007- 2008. According to the data gathered from the literature, it was determined that one species (Bathyporeia elegans *Watkin, 1938*) *was a new record for the Turkish seas and 37 species for the Marmara Sea. In the Bandırma Gulf, of the ecological variables of the environment temperature was determined to range between 6.6-27°C, salinity between 21.32-36.03 psu, dissolved oxygen between 4.04-11.26 mg $l^{-1}$and pH between 8.00-8.38. In the Erdek Gulf, temperature ranged between 6.7 and 27°C, salinity between 21.93-35.54‰, dissolved oxygen between 3.67-13.26 mg $l^{-1}$and pH between 8.06-8.36. In the surface sediment at the sampling stations of the Bandırma Gulf, total organic carbon values were between 0.07-4.42%, total calcium carbonate between 0.88-84.82%, total phosphorus between 609-12740 μg g^{-1} and mud percentage between 1.38-79.93%. In the Erdek Gulf, total organic carbon ranged between 0.08-2.89%, total calcium carbonate between 0.74-80.06%, total phosphorus between 376-3614 μg g^{-1} and mud percentage between 2.12-95.65%.*

Key words: Amphipoda, Marmara Sea, ecology, seasonal distribution

INTRODUCTION

Amphipods are important members of macrozoobenthic communities in terms of abundancy and species diversity and their abundancy is seen as similar to the dominance of insects in the terrestrial ecosystem (LOWRY, 2003). These organims are important for ecosystem since they are used as food as well as constitute an important part of food chain, and they are valuable food sources for many economically valuable fish species as well (LUIS *et al*., 2008). Moreover, they are the most productive scavengers of sea bottom and coast line besides being more effective in the removal and recycling of coastal organic wastes compared to other animal species (GROSSE & PAULEY, 1989).

This study was conducted in the Bandırma and Erdek Gulfs which are located in the south of the Marmara Sea, on both sides of the Kapıdağ Peninsula. The Marmara Sea is a semi-enclosed basin between the continents of Europe and Asia

(BEŞIKTEPE *et al*., 1995), forming the "Turkish Straits System" along with the Istanbul Strait and the Çanakkale Strait (ÜNLÜATA *et al*., 1990). Surrounded by an increasing number of industrial facilities, this sea has become a discharge area for domestic waste water as a result of unplanned urbanization due to rapid population increase as well as industrial waste water flowing from these facilities located in high numbers on the coasts. Moreover, with intense sea traffic it faces the negative effects of the contaminants, which influence the ecosystem negatively.

There are studies on amphipod species conducted by OKUŞ (1989), YÜKSEK (1989), BALKIS (1992) and ERYILMAZ (1997) in the Marmara Sea. However, there is no detailed study on the systematics and ecological characteristics of amphipods in the Bandırma and Erdek Gulfs.

The aim of this study is to determine the amphipod species inhabiting between the 0.5 and 30 m depths of the Bandırma and Erdek Gulfs and provide information about the ecological characteristics of the environment where these species inhabit. By this way, the ecological characteristics of the environment and how these characteristics affect the distribution of the amphipods will be determined. Moreover, a comparative analysis of ecological characterics of the Bandırma Gulf and the Erdek Gulf, which is thought to be cleaner compared to the former, will be performed and the contamination state of both gulfs will be identified.

MATERIAL AND METHODS

Sampling area

The sampling was performed between 2007 and 2008, on the coast (0.5 m) and at different depths from the coast towards offshore (1 m, 5 m, 10 m, 20 m, 30 m) seasonally (Fig. 1). Depths, coordinates and biotope characteristics of the stations studied in the Bandırma and Erdek Gulfs are shown in Table 1.

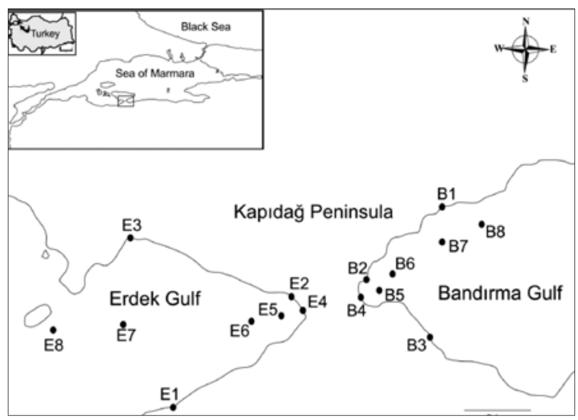

Fig. 1. Sampling stations in the Bandırma and Erdek Gulfs

Table 1. Depths, coordinates and biotope characteristics of the stations in the Bandırma and Erdek Gulf

Stations	Depth (m)	Coordinates	Biotopes
Bandırma Gulf			
B1	0.5	40°40′64″N-27°92′16″E	*Mytilus galloprovincialis* Lamarck, 1819, photophilic algae
B2	0.5	40°38′54″N-27°89′61″E	*Mytilus galloprovincialis*, photophilic algae
B3	0.5	40°35′06″N-27°91′72″E	*Mytilus galloprovincialis*, photophilic algae
B4	1	40°38′07″N-27°89′52″E	Bivalve, gastropod, sand
B5	5	40°38′28″N-27°89′89″E	*Spisula subtruncata*(da Costa, 1778), sand
B6	10	40°38′67″N-27°90′47″E	*Spisula subtruncata*, sand
B7	20	40°39′58″N-27°92′31″E	Mud and shell
B8	30	40°40′06″N-27°93′50″E	Mud and shell
Erdek Gulf			
E1	0.5	40°34′69″N-27°82′89″E	*Mytilus galloprovincialis*, photophilic algae
E2	0.5	40°37′97″N-27°87′02″E	Rock, photophilic algae
E3	0.5	40°39′81″N-27°81′56″E	*Mytilus galloprovincialis*, photophilic algae
E4	1	40°37′56″N-27°87′50″E	Sand
E5	5	40°37′54″N-27°86′89″E	Mud and shell
E6	10	40°37′39″N-27°85′47″E	Mud and shell
E7	20	40°37′25″N-27°81′78″E	Mud and shell
E8	30	40°36′92″N-27°78′89″E	Mud and shell

In the Marmara Sea which has a two-layer water column, the brackish Black Sea waters with 17.6 psu salinity flow towards the Marmara Sea through the Istanbul Strait with a surface current, and the Mediterranean-based waters with about 38.5 psu salinity flow towards the Black Sea through the Çanakkale Strait with subsurface current. There is an intermediate layer of salinity at 25 m depth between these two water layers which do not mix with each other due to the difference between their densities. The density stratification in the halocline impedes oxygen intake to the lower layer from the surface layer rich in oxygen. In addition, the increase in the oxygen consumption due to the biogenic particles at the bottom leads to the decrease in the dissolved oxygen content of the lower layer waters.The dissolved oxygen source of the lower layer waters with low oxgen content is the Meditarranean Sea waters with high salinity and dissolved oxygen content (YÜCE & TÜRKER, 1991; BEŞIKTEPE *et al*., 2000).

Sampling procedure

Amphipod samples were collected with a skimmer and a scraper from the coastal station while they were collected from other depths with Van Veen Grab which has 0.1 m^2 sampling field. Two replicates were collected at each site. Grab samples were sieved through a 1 mm mesh and all specimens were preserved in 4% formaldehyde prepared in seawater. Species were identified using a range of references (BELLAN-SANTINI *et al*., 1982; 1989; 1993; 1998; D'ACOZ&VADER, 2005). Nomenclature of the species follows ERMS (2011).

Analytical procedure

The values of temperature (ºC), salinity (psu), dissolved oxygen (mg l^{-1}) determined in the measurements were considered in order to determine the physical-chemical properties of sea water. Temperature was measured by thermometer on the water sampler. The Mohr-Knudsen method (IVANOFF, 1972) was used to measure salinity, and the Winkler method (WINKLER, 1888) to measure dissolved oxygen (DO).

Total carbonate contents were determined using a gasometric-volumetric method (LORING & RANTALA, 1992). Total organic carbon (TOC) was analyzed using the Walkey-Blake method, which involves titration after a wet combustion of the samples (GAUDETTE *et al*., 1974; LORING & RANTALA, 1992).Total phosphorus content was measured by colorimetric methods (EATON *et al.* 1995). Mud percentage was determined by GALEHOUSE (1971) and MC MANUS (1991) methods.

Statistical analysis

SOYER's (1970) frequency index was used to determine the frequency of the amphipods in the study area and results were evaluated as constant (F≥50%), common (50%>F≥25%) and rare (F<25%). Dominancy Index Formula was used to determine the dominance of amphipod species (BELLAN-SANTINI *et al*., 1969). In the statistical analyses which were conducted to determine species diversity and the distribution of species at the stations, the soft-bottom stations (B4, B5,B6,B7, B8, E4, E5, E6, E7, E8) where sampling was carried out using a Van Veen Grab with a sampling area of 0.1 m^2 were evaluated. Using the composition of the number of species and the number of individuals at the sampling stations Shannon-Weaver Diversity Index (*H'*) was performed (ZAR, 1984). Bray-Curtis Similarity Index was performed in order to determine the similarity between the sampling stations and Multidimensional Scaling (MDS) was performed in order to analyze the regional distribution pattern (CLARKE & WARWICK, 2001). SIMPER analyses were performed to identify the percentage of the contribution of each species to the similarities and differences within the groups formed after mass analysis. Correlations between depth and other abiotic factors and between biotic and abiotic parameters were determined using Spearman's rank correlation coefficient (SIEGEL, 1956).

RESULTS

Ecological data

Temperature (ºC), salinity (psu), and dissolved oxygen (mg l^{-1}) in the sea water and total organic carbon (‰), total carbonate (‰), total phosphorus (µg g^{-1}) and mud percentage values in the surface sediment samples are shown in Table 2. In the Bandırma Gulf, of the ecological variables of the environment temperature was determined to range between 6.6-27°C, salinity between 21.32-36.03psu, dissolved oxygen between 4.04-11.26 mg l^{-1}1and pH between 8.00-8.38. In the Erdek Gulf, temperature ranged between 6.7 and 27°C, salinity between 21.93-35.54psu, dissolved oxygen between 3.67-13.26 mg l^{-1}and pH between 8.06-8.36. In the surface sediment at the sampling stations of the Bandırma Gulf, total organic carbon values were between 0.07-4.42%, total calcium carbonate between 0.88-84.82%, total phosphorus between 609-12740 µg g^{-1} and mud percentage between 1.38-79.93%. In the Erdek Gulf, total organic carbon ranged between 0.08-2.89%, total calcium carbonate between 0.74-80.06%, total phosphorus between 376-3614 µg g^{-1} and mud percentage between 2.12-95.65%.

Amphipod species and seasonal distributions

Table 3 shows 66 amphipod species identified in the Bandırma and Erdek Gulfs, the stations where they were found and their Frequency Index values.

The frequency of the identified amphipod species in the study area were evaluated according to SOYER (1970) frequency index (F_S), and as a result six species *(Ampithoe ramondi, Apocorophium acutum, Dexamine spinosa, Microdeutopus algicola, Microdeutopus gryllotalpa, Phtisica marina*) were grouped as ‘constant’, 14 species (*Ampelisca diadema*, *Ampelisca pseudosarsi, Caprella acanthifera, Ericthonius punctatus, Gammarus subtypicus, Hyale crassipes, Hyale schmidti, Jassa marmorata, Melita palmata, Microdeutopus versiculatus, Monocorophium acherusicum, Monocorophium insidiosum, Perioculodes longimanus longimanus, Stenothoe monoculoides*) as ‘common’ and the remainder species (46 species) as ‘rare’.

During the sampling period, totally 49 amphipod species were identified in the Bandırma Gulf and 52 in the Erdek Gulf. While 12 of the species identified in the former (*Ampithoe ramondi, Caprella acanthifera, Ericthonius punctatus, Hyale schmidti, Jassa marmorata, Melita palmata, Microdeutopus algicola, Microdeu-*

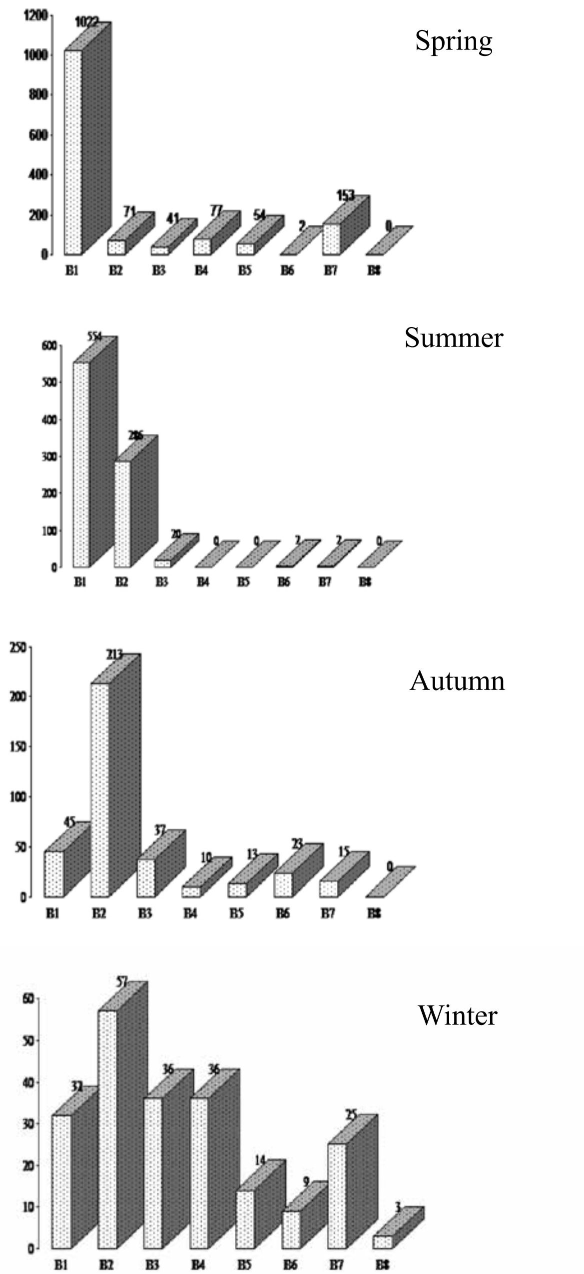

Fig. 2. Seasonal changes in the individual numbers at the sampling stations in the Bandırma Gulf

Table 2. Physicochemical parameters at the sampling stations in the Bandırma and Erdek Gulfs

Sea Water					Surface Sediment			
Stations	**Sampling Period**	**T (°C)**	**S (psu)**	**DO (mg l^{-1})**	**TOC (%)**	**$CaCO_3$ (%)**	**TP (µg g^{-1})**	**Mud Percentage (%)**
B1	Spring	19.2	23.73	10.30	0.58	1.77	12740	3.03
	Summer	27.0	21.85	6.28	0.21	1.11	822	
	Autumn	13.5	26.20	7.87	0.16	1.11	640	
	Winter	9.6	22.57	6.53	0.90	1.14	647	
B2	Spring	22.2	21.32	10.59	0.20	1.33	1016	5.57
	Summer	26.0	22.34	10.76	0.21	3.34	1062	
	Autumn	14.0	26.06	10.13	0.72	1.85	921	
	Winter	8.2	25.05	7.59	0.90	1.43	847	
B3	Spring	20.5	21.50	11.26	0.14	10.60	977	1.38
	Summer	26.0	22.17	8.88	0.16	6.82	724	
	Autumn	13.0	25.53	8.21	0.65	9.64	823	
	Winter	8.9	25.57	7.72	0.95	8.00	844	
B4	Spring	18.6	21.61	7.60	0.58	0.88	1546	1.77
	Summer	27.0	21.85	7.53	0.47	1.11	1305	
	Autumn	14.0	26.20	7.45	0.70	1.11	1541	
	Winter	7.0	25.83	5.74	1.05	1.91	1631	
B5	Spring	15.1	23.81	9.23	0.07	1.33	1232	1.83
	Summer	26.0	21.52	8.42	0.31	1.11	1373	
	Autumn	13.5	25.93	6.70	0.75	1.48	1143	
	Winter	6.6	24.92	5.97	1.18	1.43	695	
B6	Spring	18.0	22.02	8.16	4.42	24.74	3741	1.98
	Summer	26.0	23.48	7.52	0.47	2.97	1175	
	Autumn	13.5	25.93	5.71	0.70	2.59	841	
	Winter	6.6	25.57	5.83	0.49	4.19	609	
B7	Spring	14.4	22.70	10.61	0.83	84.82	2077	50.01
	Summer	19.0	27.71	7.34	2.35	17.79	6768	
	Autumn	14.0	26.33	6.38	1.47	65.23	3193	
	Winter	7.0	26.30	5.46	1.99	59.46	2719	
B8	Spring	16.4	32.33	4.40	2.97	11.49	3196	79.93
	Summer	15.5	36.03	4.56	1.09	10.38	3245	
	Autumn	16.5	33.32	5.91	1.99	13.34	2677	
	Winter	14.5	25.57	4.04	2.81	10.67	3400	
E1	Spring	21.9	22.11	9.44	0.30	12.37	376	2.14
	Summer	27.0	22.32	10.14	0.26	8.90	1613	
	Autumn	13.0	25.26	9.74	0.63	8.15	751	
	Winter	10.6	25.96	7.43	1.38	5.34	1200	
E2	Spring	21.8	21.93	8.69	0.31	1.77	487	2.59
	Summer	27.0	23.64	13.26	0.08	1.11	615	
	Autumn	13.0	26.74	7.86	0.62	0.74	576	
	Winter	14.4	25.83	9.05	1.27	0.76	850	
E3	Spring	18.3	22.32	9.02	0.55	6.27	3614	12.44
	Summer	25.0	22.82	9.97	0.08	8.90	1145	
	Autumn	13.0	27.00	8.25	0.38	0.82	1526	
	Winter	8.0	25.83	8.16	1.72	10.29	1233	
E4	Spring	18.3	22.32	6.28	0.48	3.98	744	2.12
	Summer	24.5	23.15	9.17	0.16	1.48	650	
	Autumn	13.0	26.33	6.88	0.43	3.85	757	
	Winter	6.8	26.23	7.16	1.15	1.52	857	
E5	Spring	17.9	22.51	6.23	0.91	66.09	1128	15.43
	Summer	24.0	23.15	7.75	0.71	59.30	860	
	Autumn	13.2	26.20	6.50	1.16	59.60	1716	
	Winter	6.8	25.96	8.14	2.04	59.46	1004	
E6	Spring	17.3	22.84	6.29	0.98	77.05	1643	10.92
	Summer	23.0	23.48	8.88	1.96	80.06	834	
	Autumn	13.7	26.47	6.44	0.77	45.37	1175	
	Winter	6.7	26.62	7.0	1.65	70.13	1677	
E7	Spring	14.0	26.10	6.68	1.22	74.22	2874	35.98
	Summer	17.0	34.73	6.30	0.63	23.72	823	
	Autumn	14.2	27.41	6.38	1.21	35.29	1155	
	Winter	6.8	25.70	7.43	2.69	56.41	1494	
E8	Spring	15.5	34.23	3.67	1.93	7.95	2556	95.65
	Summer	16.5	35.54	7.34	1.33	18.53	1985	
	Autumn	16.5	34.26	7.52	2.32	17.49	1319	
	Winter	6.8	26.75	7.17	2.89	9.15	1564	

Table 3. Amphipod species identified in the Bandırma and Erdek Gulfs, their stations and frequency index values (F_s)

	BANDIRMA GULF								**ERDEK GULF**								
Amphipod Species	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**F_s (%)**
Ampelisca diadema (Costa, 1853)					*	*							*		*		25
A. jaffaensis Bellan-Santini&Kaim-Malka,1977															*	*	12.5
A. pseudosarsi Bellan-Santini&Kaim-Malka,1977					*	*	*					*	*	*	*		43.75
A. pseudospinimana Bellan-Santini&Kaim-Malka,1977							*										6.25
A. rubella A.Costa, 1864															*	*	12.5
A. ruffoi Bellan-Santini&Kaim-Malka,1977							*	*							*		18.75
A. sarsi Chevreux, 1888							*			*							12.5
A. tenuicornis Liljeborg, 1855					*												6.25
Ampithoe helleri Karaman, 1975	*																6.25
A. ramondi Audouin, 1826	*	*	*	*		*			*	*	*			*			56.25
A. riedli Krapp-Schickel, 1968											*						6.25
Aora spinicornis Afonso, 1976												*					6.25
Apocorophium acutum (Chevreux, 1908)	*	*	*	*	*	*								*		*	50
Apherusa bispinosa (Bate, 1857)	*								*								12.5
A. chiereghinii Giordani-Soika, 1949									*								6.25
A. mediterranea Chevreux, 1911									*								6.25
A. vexatrix Krapp-Schickel, 1979	*																6.25
Atylus massiliensis Bellan-Santini, 1975									*								6.25
Bathyporeia elegans Watkin, 1938				*													6.25
B. guilliamsoniana (Bate, 1857)	*			*	*												18.75
Caprella acanthifera Leach, 1817	*	*		*			*					*		*	*		43.75
C. danilevskii Czerniavskii, 1868									*								6.25
C. liparotensis Haller, 1879	*	*	*														18.75
C. mitis Mayer, 1890		*															6.25

C. rapax Mayer, 1890		*							*			*					18.75
Cymadusa crassicornis (Costa, 1853)	*								*	*							18.75
Deflexilodes gibbosus Chevreux, 1888													*		*		12.5
Dexamine spiniventris(Costa, 1853)									*								6.25
D. spinosa (Montagu, 1813)	*			*		*	*		*	*		*		*			50
Echinogammarus olivii (Milne-Edwards,1830)												*					6.25
Elasmopus pocillimanus (Bate, 1862)			*						*								12.5
Ericthonius punctatus (Bate, 1857)	*	*	*						*	*	*						37.5
Gammarella fucicola (Leach, 1814)								*					*				12.5
Gammarus crinicornis Stock, 1966			*						*								12.5
G. insensibilis Stock, 1966	*									*							12.5
G. subtypicus Stock, 1966	*		*							*	*						25
Harpinia crenulata (Boeck, 1871)															*		6.25
H. dellavallei Chevreux, 1910															*		6.25
Hyale crassipes (Heller, 1966)	*	*	*						*		*						31.25
H. grimaldii Chevreux, 1891			*						*		*						18.75
H. perieri (Lucas, 1849)		*							*		*						18.75
H. schmidti (Heller, 1866)	*	*	*			*			*		*						37.5
Jassa marmorata Holmes, 1905	*	*	*						*								25
J. ocia (Bate, 1862)											*						6.25
Leptocheirus mariae Karaman, 1973														*			6.25
Leucothoe incise (Robertson, 1892)						*		*									12.5
L. lilljeborgi Boeck, 1861						*										*	12.5
L. oboa Karaman, 1971															*		6.25
Maera grossimana (Montagu,1808)							*									*	12.5
Megaluropus massiliensis Ledoyer, 1976						*											6.25
Melita hergensis Reid, 1939									*								6.25

M. palmata (Montagu, 1804)	*	*	*	*					*	*							37.5
Metaphoxus fultoni (Scott, 1890)							*	*								*	18.75
M. simplex (Bate, 1857)							*								*		12.5
Microdeutopus algicola Della Valle, 1893	*	*			*	*	*	*	*	*				*	*		62.5
M. anomalus (Rathke, 1843)	*						*								*		18.75
M. gryllotalpa Costa, 1853	*	*	*		*	*			*	*	*		*				56.25
M. versiculatus (Bate, 1856)		*				*	*	*							*		31.25
Monocorophium acherusicum (Costa,1853)	*	*			*		*	*								*	37.5
M. insidiosum Crawford, 1937	*	*			*			*							*		31.25
Orchestia cavimana Heller, 1865	*																6.25
Orchomene humilis Costa, 1853								*									6.25
Perioculodes longimanus longimanus (Bate &Westwood, 1868)					*	*						*	*	*			31.25
Phtisica marina Slabber, 1769	*				*	*		*	*	*		*	*	*	*	*	68.75
Stenothoe elachista Krapp Schickel, 1975	*	*															12.5
S. monoculoides (Montagu, 1815)	*	*	*						*			*					31.25

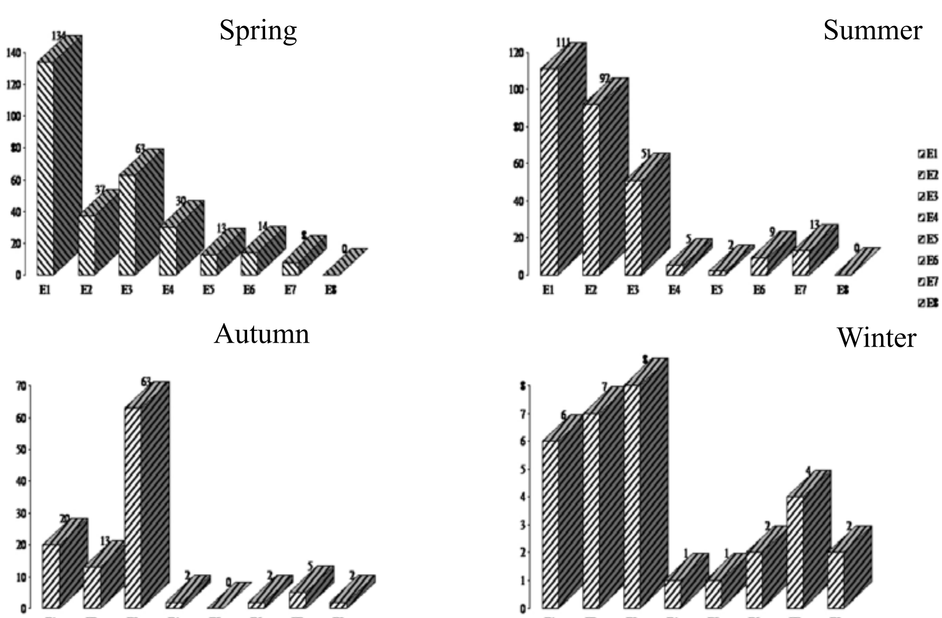

Fig. 3. Seasonal changes in the individual numbers at the sampling stations in the Erdek Gulf

Table 4. Shannon-Weaver diversity index (H′) values for the soft bottom samples from Bandırma and Erdek Gulfs

		***H′* Values**		
Stations	**Spring**	**Summer**	**Autumn**	**Winter**
Bandırma Gulf				
B4	0.34	-	1.16	0.86
B5	0.86	-	2.82	2.66
B6	-	1	1.71	2.75
B7	1.85	-	2.5	1.74
B8	-	-	-	1.59
Erdek Gulf				
E4	1.63	1.92	0.72	-
E5	2.66	-	-	-
E6	2.35	2.20	1	1
E7	2.41	2.72	0.72	1.5
E8	-	-	1	1

topus gryllotalpa, Microdeutopus versiculatus, Monocorophium acherusicum, Monocorophium insidiosum, Stenothoe monoculoides) were observed in every season during the sampling, this is applicable to only 6 of those identified in latter (*Ampithoe ramondi*, *Caprella acanthifera*, *Hyale crassipes*, *Hyale schmidti*, *Microdeutopus gryllotalpa, Stenothoe monoculoides*).

In the Bandırma Gulf, 36 species were identified in spring sampling, 25 in summer, and 28 in both autumn and winter while 37 species were identified in spring sampling, 26 in summer, 15 in autumn and 19 in winter in the Erdek Gulf. The seasonal changes in the individual numbers are shown in Fig. 2 and 3.

The analysis of the dominancy index values showed that in the Bandırma Gulf D. *spinosa* was the dominant species in spring, *M. palmata* in summer, *J. marmorata* in autumn and *M. gryllotalpa* in winter. On the other hand, in the Erdek Gulf *H. schmidti* was determined as the dominant species in all seasons except for summer when *E. punctatus* was the most dominant species and followed by *H. schmidti*.

Shannon-Weaver diversity index (*H′*) values for grab samples collected from the Bandırma and Erdek Gulfs are shown in Table 4. According to Table 4, the highest *H′* value (*H′*= 2.82) in the Bandırma Bay was recorded in autumn at Station 5 at 5 m depth and the lowest (*H′*=0) in spring at Station 6 and 8, in summer at all stations except Station 6 and in autumn at Station 8. On the other hand, in the Erdek Gulf the highest *H′* value (*H′*= 2.72) was recorded at Station 7 at 20 m depth while the lowest values (*H′*=0) were recorded at Station 8 in spring, at Station 5 and 8 in summer and at Station 4 and 5 in winter.

Bray–Curtis similarity dendrogram of the sampling stations and MDS ordination of stations produced with Bray–Curtis average clustering technique and the similarities between the stations are shown in Fig. 4 and 5.

The groups that showed the highest similarity and difference in each season and the species that contributed to the similarities and differences were determined according to SIMPER analysis results. In spring, the similarity within the third group was 69.70%, which was caused by the species *Bathyporeia guilliamsoniana* (%100) while the highest difference was observed between the second and third groups (99.06%). The species that most contributed to the difference were *Bathyporeia guilliamsoniana* (50.66%) and *Microdeutopus versiculatus* (21.49%). In summer, only one group was formed and the similarity within this group was 42.86%. *Caprella acanthifera* (33%), *Dexamine spinosa* (33%) ve *Perioculodes longimanus longimanus* (33%) were the species that contributed to the similarity. The difference between this group and Station B6 was 100%. *Caprella acanthifera* (20%) and *Perioculodes longimanus longimanus* (18.83%) were the species that most contributed to the difference. The difference between the group and Station B7 was 100%. The species that mainly contributed

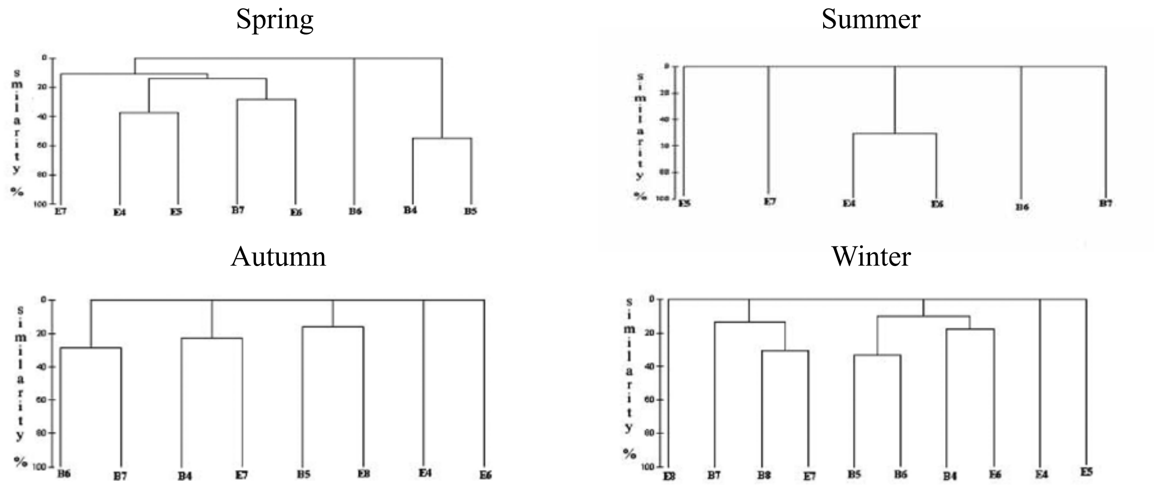

Fig. 4. Bray–Curtis similarity dendrogram of the sampling stations

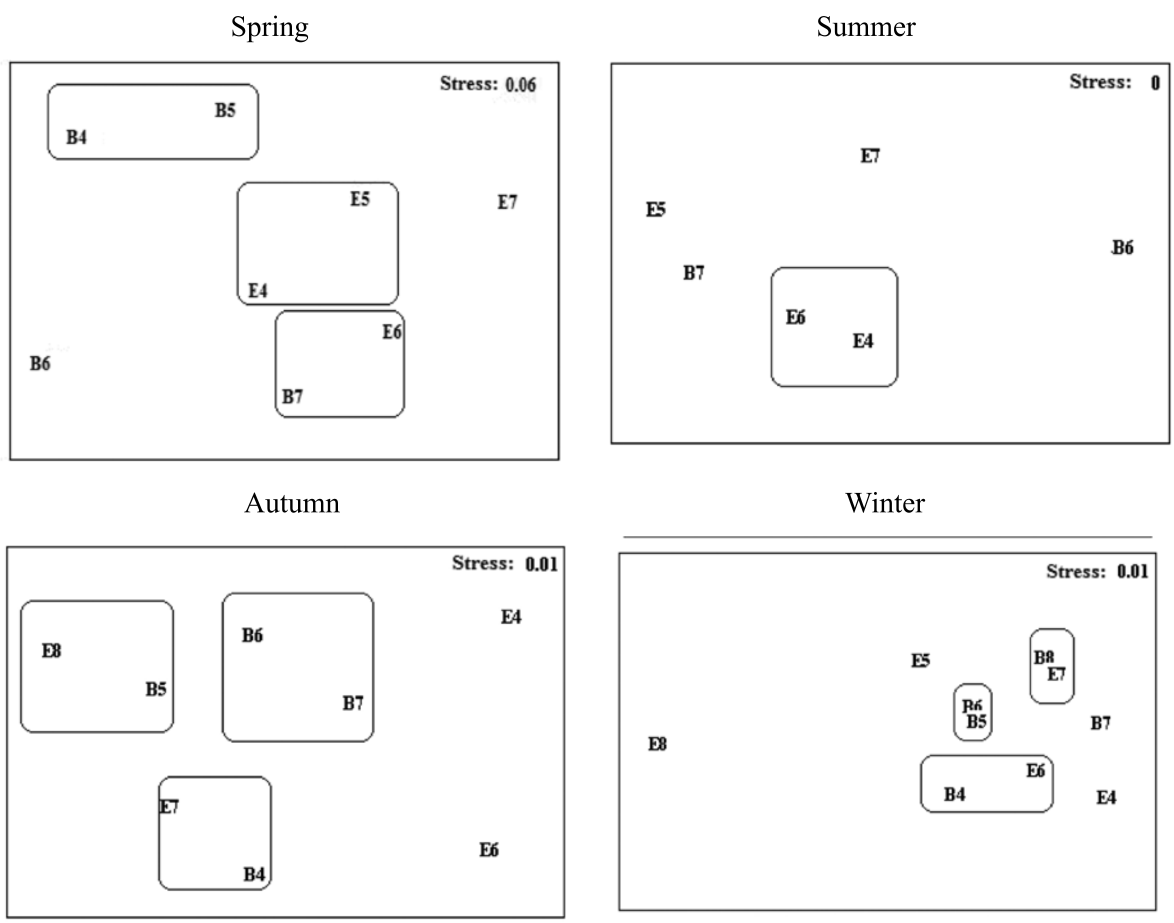

Fig. 5. MDS ordination of stations produced with Bray–Curtis average clustering technique

to the difference were *Ampelisca pseudospinimana* (23.38%), *Caprella acanthifera* (20.78%), *Perioculodes longimanus longimanus* (18.83%) and *Dexamine spinosa* (11.69%). The difference between this group and Station E5 was 100%. *Ampelisca diadema* (23.38%), *Caprella acanthifera* (20.78%), *Perioculodes longimanus longimanus* (18.83%) and *Dexamine spinosa*

Table 5. Correlation of physicochemical parameters recorded in the Bandırma and Erdek Gulfs with each other, species and individual numbers

BANDIRMA GULF									
	Specimen Number	**D (m)**	**T (°C)**	**S (psu)**	**DO (mg l^{-1})**	**TOC (%)**	**$CaCO_3$ (%)**	**TP (µg g^{-1})**	**MP (%)**
Species Number	0.784**	-0.545**	ns	ns	0.367*	-0.307*	ns	-0.402*	ns
Specimen Number		-0,675**	ns	-0,351*	0,551*	-0,443**	ns	-0,308*	ns
D			ns	0,522**	-0,622**	0,623**	0,558**	0,605**	0,537**
T				-0,499**	0,396*	-0,414**	ns	ns	ns
S					-0,605**	0,588**	0,407*	ns	0,471**
DO						-0,615**	ns	ns	-0,349*
TOC							0,573**	0,534**	0,494**
$CaCO_3$								0,449**	0,428**
TP									0,452**
ERDEKGULF									
	Specimen Number	**D (m)**	**T (°C)**	**S (psu)**	**DO (mg l^{-1})**	**TOC (%)**	**$CaCO_3$ (%)**	**TP (µg g^{-1})**	**MP (%)**
Species Number	0.863**	-0.420**	0.472**	-0.572**	ad	-0.495**	ad	ad	-0.339*
Specimen Number		-0,649**	0,529**	-0,623**	0,500**	-0,664**	ad	-0.336*	-0,395*
D			ns	0,573**	-0,667**	0,643**	0,607**	0,447**	0,708**
T				-0,559**	0,339*	-0,612**	ns	ns	ns
S					-0,432**	0,490**	ns	0,324*	0,508**
DO						-0,398**	-0,405*	-0,332*	-0,364*
TOC							0,478**	0,473**	0,580**
$CaCO_3$								0,420**	0,507**
TP									0,595**

** p<0.001
*p<0.001
ns: not significant

(11.69%) were the species that most contributed to the difference. The difference between the group and Station E7 was 100%. The species that most contributed to the difference were *Leucothoe oboa* (15.15%), *Ampelisca jaffaensis* (10.10%), *Ampelisca pseudosarsi* (10.10%) and *Microdeutopus versiculatus* (10.10%). In autumn, the highest similarity was observed in the second group. The similarity within this group was 19.05%. *Ampelisca pseudosarsi* (50%) and *Microdeutopus versiculatus* (50%) were the species that contributed to the similarity. The difference between the second and third groups was 96.19%. *Microdeutopus versiculatus* (27.98%), *Ampelisca pseudosarsi* (13.33%) and *Bathyporeia guilliamsoniana* (11.79%) were the species that mainly contributed to the difference. In winter, the highest similarity was observed in the first group. The similarity within this group was 28.57%. *Corophium insidiosum* (100%) was the species that contributed to the similarity. The difference between the first and third groups was 100%. The species that mainly contributed to the difference were *Bathyporeia guilliamsoniana* (37.98%), *Corophium acutum* (10.43%) and *Corophium insidiosum* (10.43%).

The correlation among such parameters as individual number, depth, temperature, salinity, dissolved oxygen, total organic carbon, total calcium carbonate and total phosporus was determined using Spearman's rank correlation coefficient method (SIEGEL, 1956). The results are shown in Table 5. According to the table, in the Bandırma Gulf individual number showed a significant increase in correlation the increase in species number and a significant decrease in correlation with the increase in depth, total organic carbon and total phosphorus ($p<0.01$). Individual number decreased significantly in correlation with the increase in depth, total organic carbon, total phosphorus and salinity ($p<0.05$) and increased significantly in correlation with the increase in dissolved oxygen ($p<0.05$). In the Erdek Gulf, individual number was observed to increase significantly in correlation with the increase in species number ($p<0.01$). Additionally, species number increased in correlation with the increase in temperature ($p<0.01$) and decreased in correlation with the increase in depth, salinity, total organic carbon ($p<0.01$) and mud percentage ($p<0.05$). Individual number decreased significantly in correlation with the increase in depth, salinity, total organic carbon ($p<0.01$) and mud percentage and decreased in correlation with the increase in temperature and dissolved oxygen ($p<0.01$).

DISCUSSION

After the analysis of the biotopes in which the species were found, the highest number of species and highest individual number were determined in the biotope with *Mytilus galloprovincialis* and photophilic algae. It is known that the nutritional, chemical and structural compositions of algae provide a heterogenious and very diverse food environment for herbivores, and *Mytilus* species provide a protected living space for amphipods (GROSSE & PAULEY, 1989; RIVERA & HAY, 2001). Moreover, there are a high number of studies which indicate a positive correlation between amphipods and the abundancy of microalgae living in the same environment (AIKINS & KIKUCHI, 2001; PRATO & BIANDOLINO, 2003).

There is no marked difference between the gulfs in terms of species number. One reason for this is thought to be the similar biotopic features of both gulfs. In the Bandırma Gulf, the highest species and individual numbers were recorded in spring. The species numbers recorded in the other seasons were close to each other; however, the individual number decreased gradually toward winter. The highest species and individual numbers in the Erdek Gulf were recorded again in spring. Like the Bandırma Gulf, both species and individual numbers decreased toward winter. In contrast, an increase was determined in the abundancy of epiphytic amphipods in southeastern Brazil in winter and this increase in such trophical regions as Hawaii and Brazil was followed by a sharp decrease. However, there are studies which recorded a decrease in amphipod abundancy in the same region in winter and an increase toward spring. According to the researchers, it is related to the increase in the reproduction and the growing speed of the incubating invertebrates (VALERIO-BERARDO & FLYNN, 2002). It is well-known that temperature is the most significant factor that increases reproduction and the seasonal dominance of species is also affected by reproduction periods (JACOBI, 1987; KRUSCHWITZ, 1978). Besides, the abundancy of algae, which constitute the most important living space of amphipods, is also affected by seasonal factors such as temperature and solar radiation (AIKINS & KIKUCHI, 2001). It is necessary to consider predation's effect in analyzing the abundancy of amphipod species. Predation is a highly significant factor that affects community structure, and the abundancy of amphipods, which are important food sources for fish, is limited by predation (SCHAFFNER & BOESCH, 1982).

In Table 4. the Shannon-Weaver diversity index values are low. The fact that the stations where sampling was conducted using grab included sand, and shell and mud biotopes as well as the habitat selection of amphipods have a considerable effect on the detection of low H' values.

According to the results of Bray-Curtis Similarity Index and MDS, the highest similarity in spring (54.93%) was at Stations 4 and 5 in the Bandırma Gulf. In summer, similarity (51.04%) was observed only at Stations 4 and 6 in the Erdek Gulf. The highest similarity in autumn (28.09%) was recorded at Stations 6 and 7 in the Bandırma Gulf. It was observed that similar stations had different biotopic features such as sand, shell and mud. The species that were found to contribute to similarity according to the results of SIMPER analysis were those that were determined to live both in sand and shell and mud. On the other hand, in the Bandırma Gulf the highest similarity in winter (32.91%) was determined at Stations 5 and 6 which showed similar biotopic features.

According to Spearman's rank correlation coefficient, in both gulfs species and individual numbers showed a significant increase in correlation with the decrease in depth. In the Bandırma Gulf, individual number decreased significantly in correlation with the increase in depth and salinity, and increased significantly in correlation with the increase in dissolved oxygen content. In the Erdek Gulf, species number increased in correlation with the increase in temperature and decreased in correlation with the increase in depth and salinity. Individual number decreased significantly in correlation with the increase in depth and salinity and increased in correlation with the increase in temperature and dissolved oxygen values.

In both gulfs, total organic carbon values were mostly above the shale average (0.8%) (MASON & MOORE, 1982). It is known that Gönen and Karabiga rivers have an important role in the transportation of natural terrigenous and man-made carbon into the Erdek Gulf (BALKIS & ÇAĞATAY, 2001; ALIYEV & SARI, 2005). ALBAYRAK *et al.* (2006) determined four critical TOC values as low (0.1-0.59 %), medium (0.6-1.19 %), high (1.2-2.19 %) and very high (2.2 %). When compared with these values, high and very high values were recorded at 10, 20 and 30 m depths in the Bandırma Gulf. It was observed that the values increased in autumn and winter. Similarly, high and very high values were recorded at 10, 20 and 30 m depths in the Erdek Gulf and especially in winter values were observed to increase.

Total calcium carbonate values were mostly above the shale average (6.0%) in both gulfs (MASON & MOORE, 1982). Since the stations in both gulfs included mud and sand, very high TCC values were determined. A large part of the calcium carbonate content was formed by the carbonate-dominated shells of such benthic organisms as mollusks, algae and foraminifera (ALGAN, 2000). It is thought that sediment is biogenic when TCC content is over 30% (ERGIN *et al.*, 1991).

TOC values recorded in the Bandırma and Erdek Gulfs were lower than the northern shelf (KURUN *et al.*, 2007). On the other hand, the values determined in the Erdek Gulf were observed to increase compared to the previous years (BALKIS & ÇAĞATAY, 2001).

It is noticeable that the highest phosphorus value in the surface sediment samples in the Bandırma Gulf were determined at Station 1 which is close to BAGFAS Fertilizer Factory. It is known that wastes from fertilizer and feed factories include high amounts of phosphorus and the detergent contents in domestic waste waters contain phosphorus (SUR *et al.*, 2006). Total phosphorus values of the stations were found to be above the shale average (750 µg g^{-1}) according to KRAUSKOPH (1979). Also the values in the Erdek Gulf were mostly above the shale average (KRAUSKOPH, 1979). According to SUR *et al.* (2006) the highest total phosphorus (3301 µg g^{-1}) values in the Marmara Sea were recorded in the Bandırma Gulf. According to researchers, this is related to the disposal of wastes from the agricultural lands, fertilizer and feed factories in the region as well as domestic wastes into the gulf.

According to Spearman's rank correlation coefficient, it was seen in the Bandırma Gulf that both species number and individual number decreased significantly with the increase in total organic carbon and total phosphorus content. However, individual numbers at the coastal sampling stations were very high despite high total phosphorus contents since amphipod sampling was conducted on *M. galloprovincialis* and photophilic algae on hard bottom. The decrease in the individual number with the increase in depth made us think that not only the increase in total organic carbon, total calcium carbonate and total phosphorus content but also sediment structure have a considerable effect on the decrease in individual number. The analysis of the studies on natural and artificial bottoms led us to the fact that the morphological structure and physical features of bottom have an important role in the substrate choice of amphipod species and it is mainly governed by the algal biomass and living style of the amphipod species (AIKINS & KIKUCHI, 2001).

CONCLUSIONS

In this study, 3572 amphipod individuals were recorded and 66 species from 20 families were identified with the analysis of seasonally collected species. According to the literature, one of these species is a new record for Turkish seas and 37 for the Marmara Sea. It is known that 467 benthic amphipod species live in the entire Mediterranean Sea and 110 in the Black Sea (GREZE, 1977; BELLAN-SANTINI & RUFFO, 2003; SEZGIN *et al*., 2007; BAKIR *et al*., 2008). In the studies conducted to date in the Turkish seas 319 amphipod species were determined (BAKIR, 2010). As a result of this study, the species number in the amphipod fauna of Turkish seas increased to 320 with one new record while the species number in the Marmara Sea increased to 91 with 37 new records.

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Bentoska fauna rakušaca (Crustacea) u zaljevima Bandirma i Erdek, te neki ekološki čimbenici koji utječu na njihovu raspodjelu

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SAŽETAK

Ovaj rad je imao za cilj utvrditi čimbenike okoliša koji utječu na faunu i raspodjelu vrsta bentoskih rakušaca koje nastanjuju Bandirma i Erdek zaljev na jugu Mramornog mora.

Ukupno 66 vrsta, koje pripadaju 22 obitelji, je utvrđeno nakon analize uzoraka prikupljenih sezonski na dubini između 1 i 30 m tijekom 2007.-2008. g. Na temelju podataka iz literature, utvrđeno je da vrsta *Bathyporeia elegans* Watkin, 1938 predstavlja novi nalaz u turskim morima, dok je pronađeno 37 novih jedinki u Mramornom moru.

U Bandirma zaljevu je utvrđeno da temperatura koleba u rasponu od 6,6 do 27°C, salinitet od 21.32-36.03 psu, dok je otopljeni kisik kolebao od 4,04 do 11,26 mg L^{-1} i pH od 8.00 do 8.38.

U Erdek zaljevu, temperatura se kretala od 6,7 do 27°C, salinitet od 21.93 do 35.54 psu, otopljeni kisik od 3,67 do 13,26 mg L^{-1} i pH od 8.06 do 8.36.

Analizom uzoraka površinskog sedimenta na postajama u Bandirma zaljevu otkrili, ustanovljene su vrijednosti ukupnog organskog ugljika koje su kolebale od 0,07 do 4,42%, ukupnog kalcij karbonata od 0,88 do 84,82%, ukupnog fosfora od 609 do 12740 ug g^{-1}, te postotak blata koji se kretao od 1,38 do 79,93%. Uzorci površinskog sedimenta na postajama u Bandirma zaljevu pokazali su slijedeće: vrijednosti ukupnog organskog ugljika kolebale su od 0,07 do 4,42%, ukupnog kalcij karbonata od 0.88 do 84.82%, ukupnog fosfora od 609 do 12740 ug g^{-1}, dok se postotak blata kretao od 1,38 do 79,93 %.

U Erdek zaljevu je ustanovljeno kolebanje ukupnog organskog ugljika od 0,08 do 2,89%, ukupni kalcij karbonat od 0,74 do 80,06%, ukupni fosfor od 376 do 3614 ug g^{-1}, a postotak blata se kretao od 2,12 do 95,65%.

Ključne riječi: Rakušci, Marmara Sea, ekologija, sezonska raspodjela