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Soft Bottom Molluscan Assemblages of the Bathyal Zone of the Sea of Marmara

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Abstract

This study deals with the soft bottom molluscan species collected from the bathyal zone of the Sea of Marmara in 2013. Replicated samples were taken using a Box Core, sampling an area of 0.1 m^2 at 31 stations along two depth transects, 500 and 1000 m. A total of 1229 individuals belonging to 4 classes and 28 species were collected. Two species (*Akritogyra conspicua* and *Liostomia hansgei*) are new records for the marine molluscan fauna of Turkey and four species (*Benthonella tenella*, *Odostomia silesui*, S*yrnola minuta* and *Crenilabium exile*) are new records for the molluscan fauna of the Sea of Marmara. A relatively richer fauna was determined at a depth of 500 m (25 species) compared to 1000 m (17 species).The most dominant species at 500 m and 1000 m depths were *Crenilabium exile* and *Parthenina flexuosa*, respectively. Number of species and number of individuals varied significantly only between depths, while number of individuals changed significantly among basins (ANOVA test). A significant difference in species assemblages between the Tekirdağ and the Central Basins was detected (ANOSIM test). Multivariate analysis showed that depth was the main factor influencing the molluscan assemblages in the area.

Keywords: Mollusca, Bathyal zone, New records, Taxonomy, Ecology, Distribution, Sea of Marmara.

Introduction

The Sea of Marmara, with a surface area of 11,500 km² and a maximum depth of 1390 m, is a semi-enclosed basin in the Mediterranean system located between the continents of Europe and Asia. It is connected to the Black Sea, the largest anoxic basin in the world, and the Aegean Sea through the İstanbul and Çanakkale Straits. The Sea of Marmara has two prominently different water masses; the upper layer originating from the Black Sea (from the surface to about 25 m), with brackish water (22–26‰ salinity) and a renewal time of about 5–6 months and the lower layer with more saline water (up to 38.5‰ salinity) originated from the Mediterranean Sea with a renewal time of about 6–7 years (Beşiktepe *et al.*, 1994). Because of the outflow of brackish Black Sea water, there is a strong halocline throughout the Sea of Marmara, leading to low-oxygen conditions below the thin well-mixed surface layer, at 25 m depth (Beşiktepe *et al.*, 1994; Kaminski *et al.*, 2002). On the other hand, the Sea of Marmara is subjected to high volumes of wastewater discharges from land-based sources.The basin receives a total of 1.9 x 10^6 tons of TOC (total organic carbon) and 2.7 x 10^5 tons of TN (total nitrogen) per year from the Black Sea inflow (Albayrak *et al.*, 2006), which is one of the important factors threatening biodiversity.

Studies on the molluscs of the Sea of Marmara date back to the end of 19th century. In that period, Colombo (1885) recorded certain species of different systematic groups such as Coelenterata, Bryozoa, Polychaeta, Crustacea, Mollusca, Echinodermata and Pisces from the infra and the circalittoral zones. Sturany (1895) dealt only with molluscan species from the circalittoral and bathyal (one station only) zones. Ostroumoff (1896) conducted the most detailed study in the 19th century; he performed benthic and pelagic samplings at 61 stations and reported more than 700 macrobenthic and planktonic species. Marion (1898) recorded some species of Coelenterata, Crustacea, Mollusca and Echinodermata from gravelly mud bottoms with shell fragments, at a depth of 40-42 m. Later on, further studies on the molluscan fauna of the Sea of Marmara were conducted by different authors. Among them, Demir (1952) focused on the benthic invertebrates along the shores of the Bosphorus and Prince Islands. Tortonese (1959) worked on the soft bottoms of the infra and the circalittoral zones and reported some macrobenthic species of Porifera, Polychaeta, Mollusca, Echinodermata and Tunicata. Oberling (1969-1971) investigated littoral molluscan species between Tekirdağ and Avşa Island. Yüksek (1989) studied the littoral biota of the southern coast of the Sea of Marmara. Balkıs (1992) determined the macrobenthic species of the littoral zone of Marmara Island. Albayrak & Balkis (1996a, b) and Albayrak *et al.* (2004) focused on the benthic prosobranch gastropods and the bivalvian species of the hard and the soft bottoms of the infra and the circalittoral zones of the

Bosphorus and the Sea of Marmara. Ritt *et al.* (2010) reported some macrobenthic species from the three micro habitats (bioturbated sediment, reduced sediment and carbonate crust) near a brackish-water cold seep of the bathyal zone on the North Anatolian Fault. Among the above mentioned studies, only Sturany (1895), Ostroumof (1896) and Ritt *et al.* (2010) identified molluscan specimens in some samples (8-13 samples) collected at depths exceeding 500 m.

The aim of this paper was to elucidate the composition and the structure of the molluscan assemblages occurring in the bathyal zone of the Sea of Marmara and their relationship with environmental variables.

Materials and Methods

Study Area

The Sea of Marmara is divided into three major subbasins with bathyal zones, namely, Tekirdağ, Central and Çınarcık. They are about 1200 m deep and separated by saddles as shallow as 400–600 m (McHugh *et al.*, 2008). Among these, the Çınarcık Basin, which is located south of the Prince Islands, has a maximum depth of 1270 m. The Central Basin, which is located between Marmara Ereğlisi and Kapıdağ Peninsula, harbours the deepest point (1268 m) of the Sea of Marmara. The Tekirdağ Basin, which is situated in front of the Ganos Mountains, has a maximum depth of 1133 m (Gazioğlu *et al.*, 2002).

Data collection

The benthic material was collected from 31 stations in the bathyal zone of the Sea of Marmara (Fig. 1; Table 1) by R/V Yunus-S in June 2013. All material was collected using a Box Core, sampling an area of 0.1 m^2. The first 30 cm of the sediment samples were evaluated. Some samples could not be taken at some stations (Table 1) due to the weather conditions and the bottom structure. No sample could be taken at 500 m depth of station 34, as the bottom was covered with rocks. At each station, three replicates were taken for benthic community analysis and an additional sample for granulometric and chemical analysis of the sediment. Samples were sieved with a 0.5 mm mesh on board the R/V Yunus-S and the retained material was placed in jars containing seawater with 4% formaldehyde solution. In addition to the box-core sampler, we also used a bottom-trawl to sample large-sized deep-sea faunal components of the Sea of Marmara. However, no molluscan specimens were gathered by this bottom-trawl hauling (one in each basin). At the laboratory, the material was washed with tap water and specimens were sorted according to taxonomic groups under a stereomicroscope. The sorted specimens were then preserved in 70% ethanol. The molluscan specimens were identified and counted under stereomicroscopes. Bottom-water samples were taken with a CTD bottle at each station during sampling. Temperature, salinity and dissolved oxygen concentrations were determined on board the R/V Yunus-S. Water samples for analysing nitrite, nitrate, ammonia, phosphate phosphorus and silicate were pre-filtered, frozen and immediately transferred to the laboratory.

Data analysis

Community parameters such as number of species, number of individuals, Shannon–Wiener's diversity index (log_2 base) (H´) and Pielou's evenness index (J´) were calculated for the samples. In order to determine

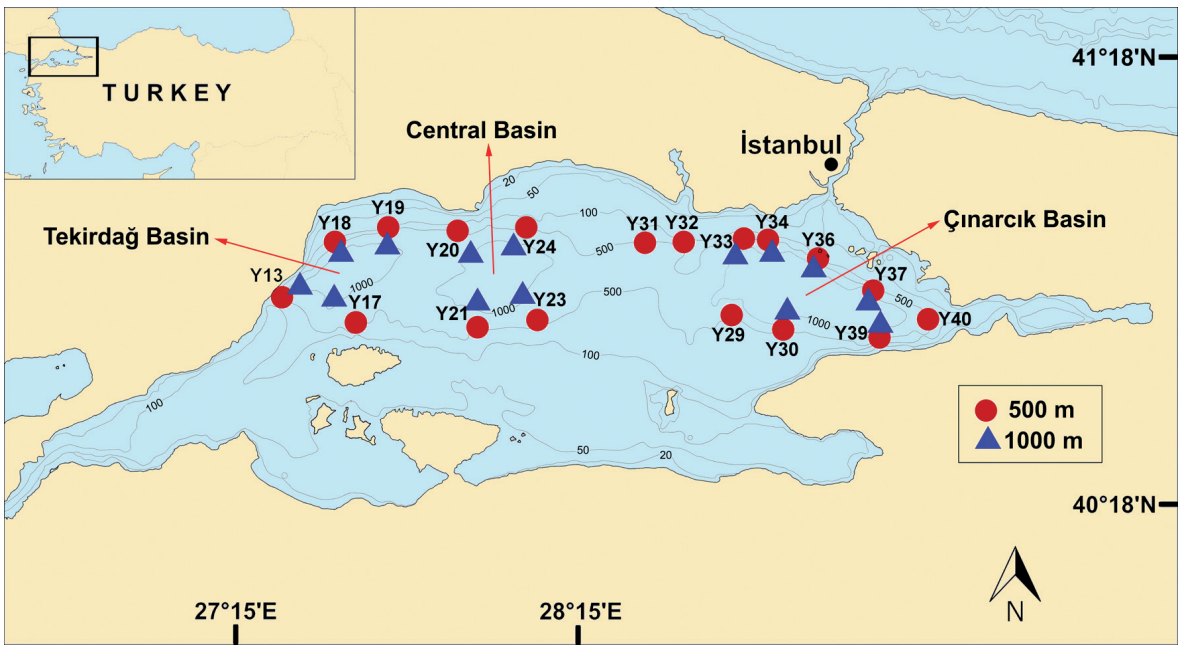

Fig. 1: Map of the investigated area and sampling sites.

Table 1. Coordinates, sampling dates, number of sample (N) depth and bottom structure of the sampled stations.

Stations	Latitude	Longitude	Date	Depth (m)	N	Sediment type
Y13_500	40.773056° N	27.395278° E	10.06.2013	500	3	Clay
Y13_1000	40.796944° N	27.443056° E	10.06.2013	1000	2	Clay
Y17_500	40.711667° N	27.616389° E	09.06.2013	500	3	Clay
Y17_1000	40.764167° N	27.549444° E	09.06.2013	1000	3	Clay
Y18_500	40.892500° N	27.551111° E	10.06.2013	500	3	Clay with shell fragments
Y18_1000	40.873333° N	27.563611° E	10.06.2013	1000	2	Clay
Y19_500	40.926389° N	27.709722° E	11.06.2013	500	3	Gravelly clay
Y19_1000	40.883611° N	27.706944° E	11.06.2013	1000	2	Clay
Y20_500	40.918611° N	27.912500° E	13.06.2013	500	3	Clay
Y20_1000	40.881667° N	27.927222° E	12.06.2013	1000	2	Clay
Y21_500	40.703611° N	27.967778° E	15.06.2013	500	3	Clay
Y21_1000	40.756667° N	27.970000° E	15.06.2013	1100	2	Clay
Y23_500	40.716667° N	28.151111° E	15.06.2013	500	3	Clay
Y23_1000	40.775278° N	28.096944° E	15.06.2013	1000	2	Clay
Y24_500	40.927778° N	28.112500° E	13.06.2013	500	3	Clay
Y24_1000	40.881944° N	28.074722° E	13.06.2013	1190	1	Clay
Y29_500	40.733056° N	28.721389° E	17.06.2013	500	3	Clay
Y30_500	40.698611° N	28.871944° E	17.06.2013	500	3	Clay
Y30_1000	40.732222° N	28.880556° E	17.06.2013	1030	3	Clay
Y31_500	40.891667° N	28.458889° E	23.06.2013	500	3	Clay
Y32_500	40.892222° N	28.571111° E	23.06.2013	500	3	Gravelly clayey sand
Y33_500	40.901111° N	28.748611° E	23.06.2013	500	3	Clay
Y33_1000	40.861111° N	28.729167° E	23.06.2013	1000	1	Clay
Y34_1000	40.872222° N	28.836944° E	24.06.2013	1000	1	Clay
Y36_500	40.851667° N	28.967500° E	22.06.2013	500	2	Clay
Y36_1000	40.839722° N	28.958889° E	22.06.2013	1000	1	Gravelly sand with shell fragments
Y37_500	40.783611° N	29.132500° E	21.06.2013	500	3	Gravelly clay
Y37_1000	40.765556° N	29.120556° E	21.06.2013	1000	1	Clay
Y39_500	40.683611° N	29.149722° E	19.06.2013	500	3	Clay with shell fragments
Y39_1000	40.702778° N	29.152500° E	19.06.2013	1215	2	Clay
Y40_500	40.720000° N	29.292500° E	19.06.2013	500	3	Clay

species distribution patterns, the abundance data of all stations were analysed using cluster and multidimensional scaling (MDS) techniques, based on the Bray–Curtis similarity index (group average technique). The groups of stations (A, B and C) on the dendrogram were highlighted in grey. The relationship between environmental variables and patterns of similarity of the mollusc assemblages was assessed by the MDS plot with superimposed vectors whose correlation is higher than 0.3, using the PRIMER package (Clarke & Warwick, 2001). Prior to the cluster and multidimensional scaling analyses, the raw data (number of individuals) were transformed using they $y_{ji} = \log(x_{ji} + 1)$ equation. Pearson's correlation analysis was used to assess relationships between environmental variables and community parameters.

The differences in the number of species, number of individuals, diversity and evenness index values were tested using ANOVA. Pairwise analysis of similarities (ANOSIM) was carried out to test significant differences regarding depths, basins and sediment types.

Nutrients and chlorophyll-a were analysed using a spectrophotometer (Parsons *et al.*, 1984). Total organic carbon concentration (TOC) in each sediment sample was estimated according to the modified Walkley Black titration method (Gaudette *et al.*, 1974). Granulometric analyses were carried out according to Erguvanli (1995). Three particle size fractions were determined including sand (2 mm-0.063 mm), silt (0.063 mm-0.002 mm) and clay (<0.002 mm). The physical & chemical properties of the stations will be presented at a later date by Aksu *et al.* (in preparation).

The specimens identified in this study were deposited at the Museum of the Faculty of Fisheries, Ege University (EFSM), İzmir, Turkey.

Results

Examination of materials obtained from 31 stations revealed a total of 28 molluscan species and 1229 indi-

viduals belonging to 4 classes (Caudofoveata, Gastropoda, Bivalvia and Scaphopoda). The class Caudofoveata was represented by one species and one individual, Gastropoda by 22 species and 1162 individuals, Bivalvia by 4 species and 54 individuals and Scaphopoda by 1 species and 12 individuals (Table 2).

Among the classes, Gastropoda accounted for 91% and 96% of the total number of specimens collected at depths of 500 and 1000 m, respectively (Table 2). The dominant species at 500 m depth were *Crenilabium exile* (26.37% of total individuals), *Parthenina flexuosa* (15.02%), *Alvania cimicoides* (9.16%) and *Megastomia conoidea* (8.42%), all comprising 59% of total specimens (Table 2). *Parthenina flexuosa* was the most dominant (60.46%) species at 1000 m depth, followed by *C. exile* (22.28%), *B. tenella* (6.17%) and *Yoldiella philippiana* (3.66%).

The most frequent species at 500 m depth were *A. cimicoides* and *C. exile* (each present in 32% of the samples), *Megastomia conoidea* (18%), *P. flexuosa* (16%), *S. minuta* (16%) and *Cylichna cylindracea* (16%) (Table 2). *Parthenina flexuosa* and *C. exile* were the most frequent species (72% each) at 1000 m and deeper.

The mean number of species and number of individuals, diversity and evenness values at all stations are presented in Figure 2. The highest number of species was encountered at 1000 m, at station Y37 (7 species) and Y20 (6 species), and at 500 m depth, at station Y40 (6 species). Among 31 sampling stations, four stations (Y17_500, Y21_500, Y31_500 and Y32_500) did not have any molluscan species. Station Y20_1000 had the highest molluscan density (1560 ind. m^{-2}), followed by Y23_1000, Y24_1000 and Y39_1000 (640 ind.m^{-2} in

Table 2. List of species and number of individuals (N) recorded at two different sampling depths (500 and 1000 m) in the Sea of Marmara, with their dominancy (D%) and frequency values (F%).

Groups/Species	N (500 m)	N (1000 m)	F% (500m)	F% (1000 m)	D% (500 m)	D% (1000 m)
CAUDOFOVEATA						
Falcidens gutturosus (Kowalewsky, 1901)	1		2.00		0.37	
GASTROPODA						
Putzeysia wiseri (Calcara, 1842)	10	3	10.00	4.00	3.66	0.31
**Akritogyra conspicua* (Monterosato, 1880)	5	7	6.00	12.00	1.83	0.73
Bittium submamillatum (de Rayneval & Ponzi, 1854)	3		4.00		1.10	
Alvania cimicoides (Forbes, 1844)	25	24	32.00	24.00	9.16	2.51
Alvania punctura (Montagu, 1803)	3		6.00		1.10	
***Benthonella tenella* (Jeffreys, 1869)	6	59	6.00	36.00	2.20	6.17
Pusillina inconspicua (Alder, 1844)	3		2.00		1.10	
Laeviphitus verduini van Aartsen, Bogi & Giusti, 1989		3		8.00		0.31
Ceratia proxima (Forbes & Hanley, 1850)	2		4.00		0.73	
Hyala vitrea (Montagu, 1803)	5	1	6.00	4.00	1.83	0.10
**Liostomia hansgei* Warén, 1991		4		12.00		0.42
Mangelia nuperrima (Tiberi, 1855)	2		4.00		0.73	
Megastomia conoidea (Brocchi, 1814)	23	11	18.00	36.00	8.42	1.15
***Odostomia silesui* Nofroni, 1988	2		2.00		0.73	
Odostomia unidentata (Montagu, 1803)	1		2.00		0.37	
Parthenina flexuosa (Monterosato, 1874)	41	578	16.00	72.00	15.02	60.46
Parthenina interstincta (Adams, J., 1797)	1		2.00		0.37	
***Syrnola minuta* H. Adams, 1869	20	5	16.00	12.00	7.33	0.52
Turbonilla micans (Monterosato, 1875)		2		8.00		0.21
***Crenilabium exile* (Jeffreys, 1870)	72	213	32.00	72.00	26.37	22.28
Roxania utriculus (Brocchi, 1814)	16	3	12.00	4.00	5.86	0.31
Cylichna cylindracea (Pennant, 1777)	9		16.00		3.30	
BIVALVIA						
Yoldiella philippiana (Nyst, 1845)	5	35	2.00	44.00	1.83	3.66
Lucinoma borealis (Linnaeus, 1767)	2		2.00		0.73	
Lucinoma kazani Salas & Woodside, 2002	1		2.00		0.37	
Myrtea amorpha (Sturany, 1896)	8	3	2.00	4.00	2.93	0.31
SCAPHOPODA						
Entalina tetragona (Brocchi, 1814)	8	4	12.00	8.00	2.93	0.42

*Species new records for the marine molluscan fauna of Turkey, **Species new records for the Sea of Marmara.

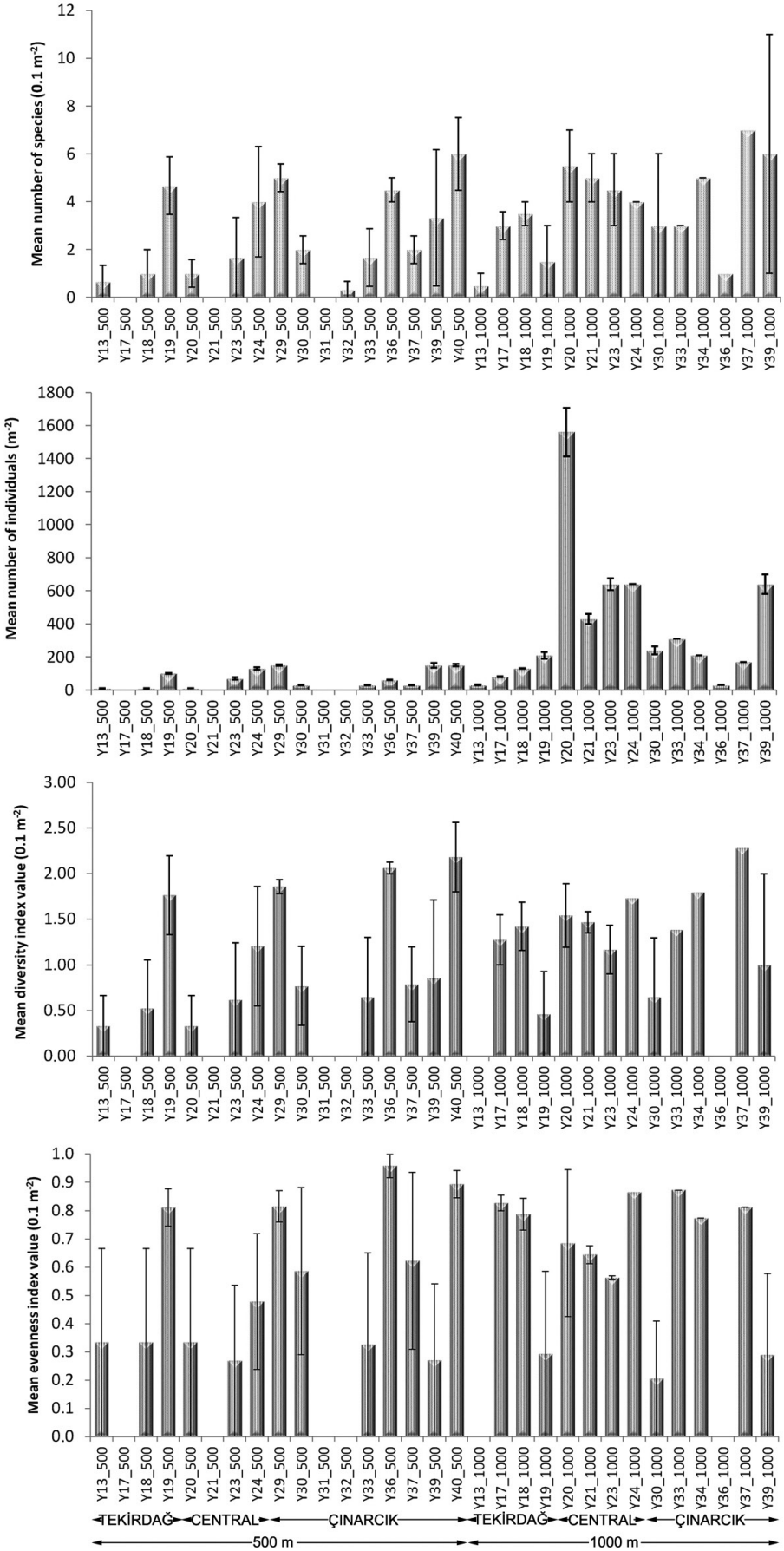

Fig. 2: Mean number of species, faunal densities (number of individuals per m^{-2}), diversity index and evenness index at each station, with ± standard errors.

each). The highest diversity index value (H'=2.27) was calculated at station Y37_1000, followed by Y40_500 (H'=2.18) and Y36_500 (H'=2.06). The highest evenness index value (J'=0.95) was found at station Y36_500, followed by Y40_500 (J'=0.89) and Y33_1000 (J'=0.87).

The maximum values of community parameters in each sample, such as number of species, number of individuals, diversity index and evenness index at all stations are presented in Figure 3. The highest number of species was found at stations Y39_1000 (11 species), Y39_500 (9 species), Y24_500 (8 species) and Y40_500 (8 species). The highest molluscan density (430 ind.m^{-2}) at 500 m depth was determined at stations Y39_500 and Y40_500 (290 ind. m^{-2}). Stations Y20_1000 (3020 ind.m^{-2}) and Y39_1000 (1240 ind.m^{-2}) had the highest molluscan densities at 1000 m depth. The highest diversity index values were calculated at stations Y40_500 (H'=2.8), Y19_500 (H'=2.62) and Y37_1000 (H'=2.27). As stations Y13_500, Y18_500, Y20_500, Y36_500 and Y37_500 had few species and specimens, the evenness index attained its maxima (J'=1) at these stations.The highest evenness index values at 1000 m were found at stations Y20_1000 (J'=0.94), Y17_1000 (J'=0.88) and Y33_1000 (J'=0.87).

Among the three basins and two different depth ranges studied, the maximum number of molluscan species was determined at depths of 1000 m and 500 m in Çınarcık Basin (Fig. 4). The highest median value of the number of species and the maximum number of individuals were found at 1000 m and more depths in the Central Basin. Tekirdağ Basin was represented by the highest diversity index values, while Çınarcık Basin and the Central Basin, at 1000 m, had the highest median values. The five hundred meter depths of all basins showed the highest evenness index values (Fig. 4).

Pearson's correlation analysis between the mean scores of community parameters and environmental variables indicated that the number of individuals and the diversity index were significantly and positively correlated with depth and total organic carbon in sediment, respectively (Table 3). The other factor significantly and negatively correlated with the number of individuals in the area was salinity (Table 3).

Based on Bray-Curtis similarity values higher than 55%, three mollusc assemblages were determined in the area (Fig. 5). The stress value for the two-dimensional MDS plot was 0.16, showing a proper group separation. Stations Y18_500, Y20_500, Y30_500 and Y33_500 formed group A (average similarity: 56.28), all deeper stations (1000 m and deeper) formed group B (average similarity: 57.9) and stations Y24_500, Y29_500, Y39_500 and Y40_500 constituted group C (average similarity: 55.45). The deepest part of the bathyal zone seemed to be homogenous in terms of molluscan assemblages, aggregation in a large group called group B. However, the molluscan assemblages were heterogeneous at 500 m depth. There were two large groupings at 500 m depth, and 4 stations at 500 m depth were placed in distant locations on the MDS plot, which joined to other groups with low similarity index values (<40%). Vectors superimposed on the MDS plot indicated the relationships between environmental variables and patterns of similarity of the mollusc assemblages (Figure 5). According to the MDS plot and the correlation values between the environmental variables and MDS axes, the depth was found to be the main factor influencing the molluscan assemblages in the study area (Fig. 5). However, the granulometric features of sediment seemed to have impacted on the distribution of molluscan species at 500 m depth. As stations Y19_500 and Y37_500 had a different habitat structure (gravelly clay bottom), the molluscan assemblages found at these stations were very different from those with clayey habitats, resulting in the placement of these stations at distant locations on the MDS graph.

According to the SIMPER analysis, *Crenilabium exile*, *Parthenina flexuosa* and *Syrnola minuta* were the species most responsible for the similarity of groups A, B and C, respectively (Table 4). *Alvania cimicoides* was another species significantly contributing to the similarity in groups A and C.

Number of species and number of individuals varied significantly only between depths (ANOVA, P<0.05). In addition, number of molluscan individuals changed significantly among basins (ANOVA, P<0.05). The ANOSIM pairwise test detected a significant difference

Table 3. Pearson's correlation coefficients calculated between community parameters and environmental variables; numbers in bold represent statistically significant correlations (P<0.05).

	Number of species	Number of individuals	Diversity index	Evenness index
Depth	-0.13	**0.56**	0.23	0.19
Temperature	-0.06	-0.22	-0.28	-0.28
Salinity	-0.12	**-0.41**	-0.04	0.00
pH	0.30	0.31	0.19	0.01
Oxygen	-0.37	0.29	-0.19	-0.01

Table 4. Species contributing significantly to the similarity within each assemblage (as shown in Fig. 5) and average similarity percentage.

Associations in Fig. 3	A		B		C	
Average similarity	**56.28**	**AA**	**57.90**	**AA**	**55.45**	**AA**
Alvania cimicoides	39.94	12.5			16.59	35.0
Benthonella tenella			8.12	45.4		
Megastomia conoidea					16.35	45.0
Parthenina flexuosa			**43.36**	447.7	8.52	80.0
Syrnola minuta					**17.75**	42.5
Crenilabium exile	**42.68**	22.5	35.40	173.1	11.89	115.0
Roxania utriculus					12.11	35.0
Cylichna cylindracea	17.38	10.0				
Yoldiella philippiana			4.01	23.1		
Entalina tetragona					9.81	17.5

Bold numbers indicate the highest score of species contribution in each assemblage.
AA: Average abundance (individuals m^{-2}).

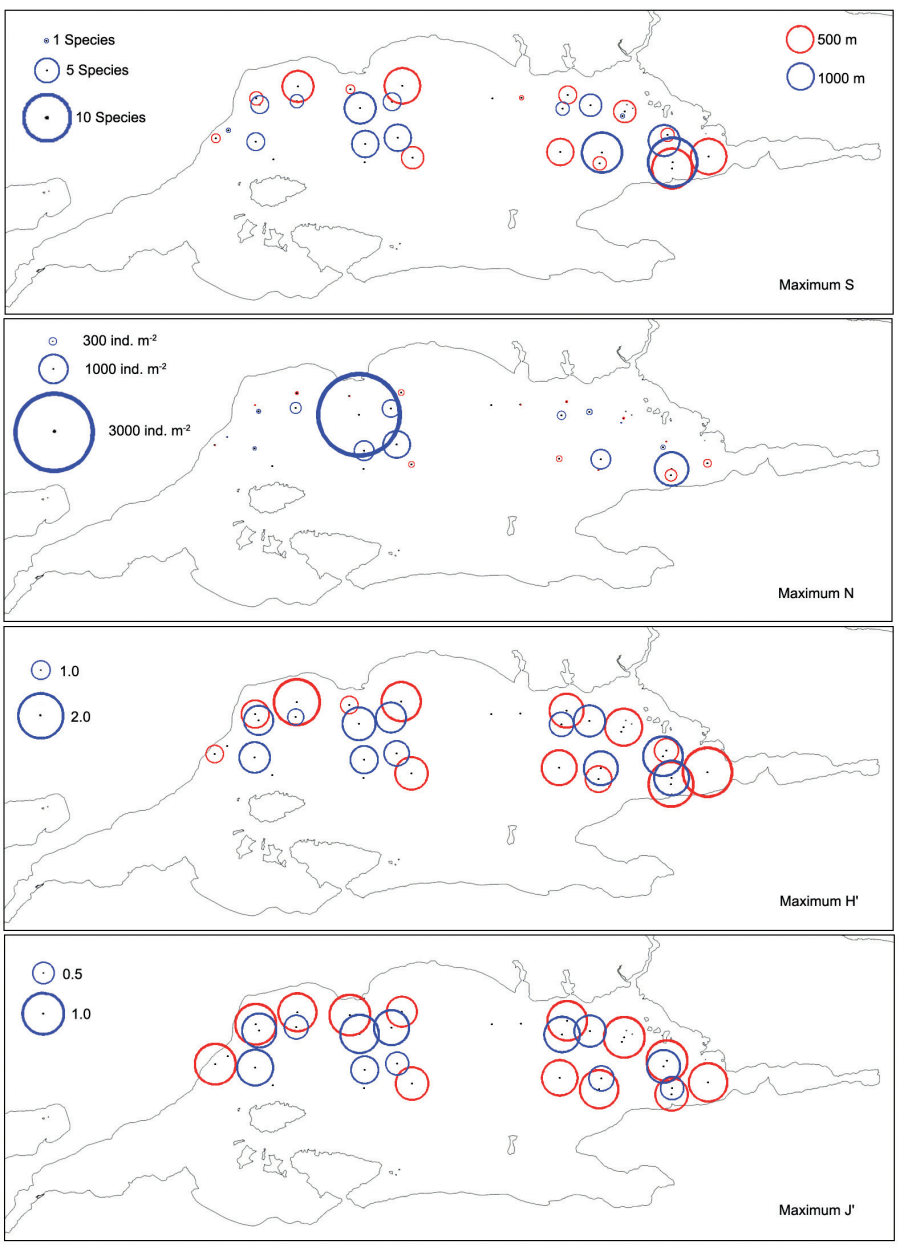

Fig. 3: Maximum number of species, faunal densities (number of individuals per m^{-2}), diversity index and evenness index values determined at each station.

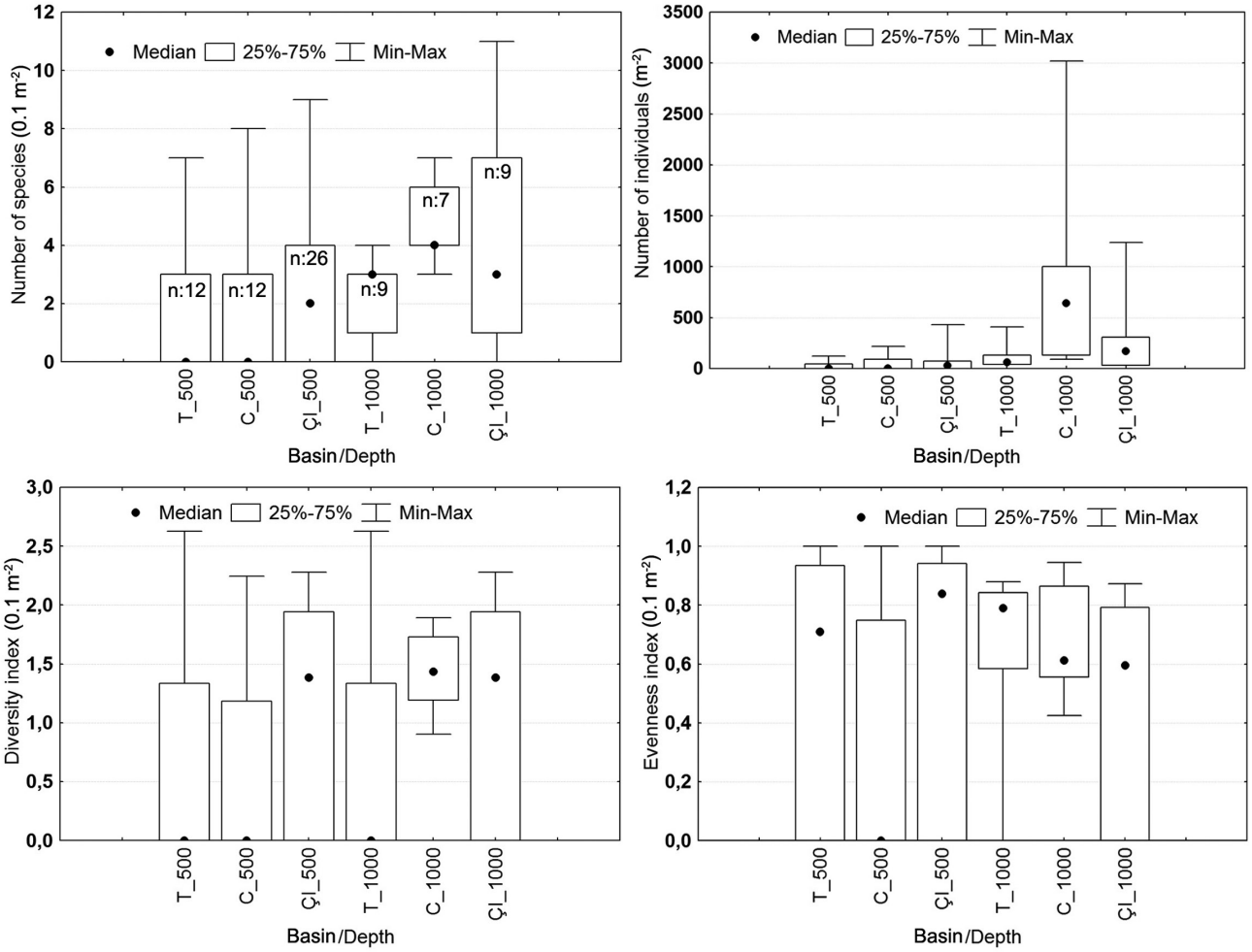

Fig. 4: Median values, 25-75 percentiles and minimum-maximum values of the number of species, faunal densities (number of individuals per m^{-2}), diversity index and evenness index determined for each basin (n: number of samples; T: Tekirdağ Basin; C: Central Basin; ÇI: Çınarcık Basin).

in species assemblages between the Tekirdağ and the Central Basins (ANOSIM, $P < 0.05$).

Discussion

Analysis of the benthic samples taken from the bathyal zone of the Sea of Marmara showed that, compared to the western Mediterranean (Gofas *et al.,* 2014; Rueda *et al*., 2015), the investigated area has a relatively poor molluscan fauna (a total of 28 species), like the other eastern parts of the Mediterranean (Bogi & Galil, 2004; Koutsoubas *et al.,* 2000; Mastrototaro *et al.,* 2010). Among the species identified, *Akritogyra conspicua* and *Liostomia hansgei* (Fig. 6) are new records for the marine molluscan fauna of Turkey, while *Benthonella tenella*, *Odostomia silesui*, S*yrnola minuta* and *Crenilabium exile* (Fig. 6) are new ones for the molluscan fauna of the Sea of Marmara. *Akritogyra conspicua* is a deep-water species recorded from depths between 100-2400 m, and was previously reported as a rare species from the central and western Mediterranean Sea (Warén, 1992). In this study, nine specimens of *Akritogyra conspicua* were found at depths between 500 and 1000 m. *Liostomia hansgei*, which was originally described from the Swedish west coast (Koster area) (Warén, 1991), is also a rarely distributed species in the Mediterranean Sea, known only from the Spanish coast (Peñas *et al.*, 1996). In our study, five specimens of this species were found at 1000 m depth.

Of the species that are new records for the Sea of Marmara, *Benthonella tenella* and *C. exile* were previously reported from the Levantine coasts of Turkey (Öztürk *et al.*, 2012; Öztürk, 2014), and *O. silesui* and *S. minuta* from the Aegean coast of Turkey (Öztürk *et al.*, 2013; Öztürk & Bitlis-Bakır, 2013).

In a previous study conducted by Ostroumoff (1896), a total of 49 mollusc species was reported in the bathyal zone of the region, of which 40 species were represented by their shells only. Out of the nine living molluscan species [*Aporrhais serresianus* (Michaud, 1828); *Odostomia unidentata* (Montagu, 1803); *Saccella commuta-*

ta (Philippi, 1844); *Yoldiella philippiana* (Nyst, 1845); *Delectopecten vitreus* (Gmelin, 1791); *Flexopecten glaber* (Linnaeus, 1758); *Kurtiella bidentata* (Montagu, 1803); *Abra longicallus* (Scacchi, 1835); *Kelliella miliaris* (Philippi, 1844)] reported by Ostroumoff (1896), only *O. unidentata* and *Y. philippiana* were encountered during our study. Besides, Ostroumoff (1896) reported live specimens of *K. miliaris* in the bathyal zones of the Sea of Marmara, but no live individuals of this species were encountered during our study. However, many dead shells of this species were found in the area, at depths of 500-1000 m.

Another study dealing with the bathyal zone communities of the Sea of Marmara was carried out by Ritt *et al.* (2010) who reported 17 mollusc species from different microhabitats such as bioturbated sediment microhabi-

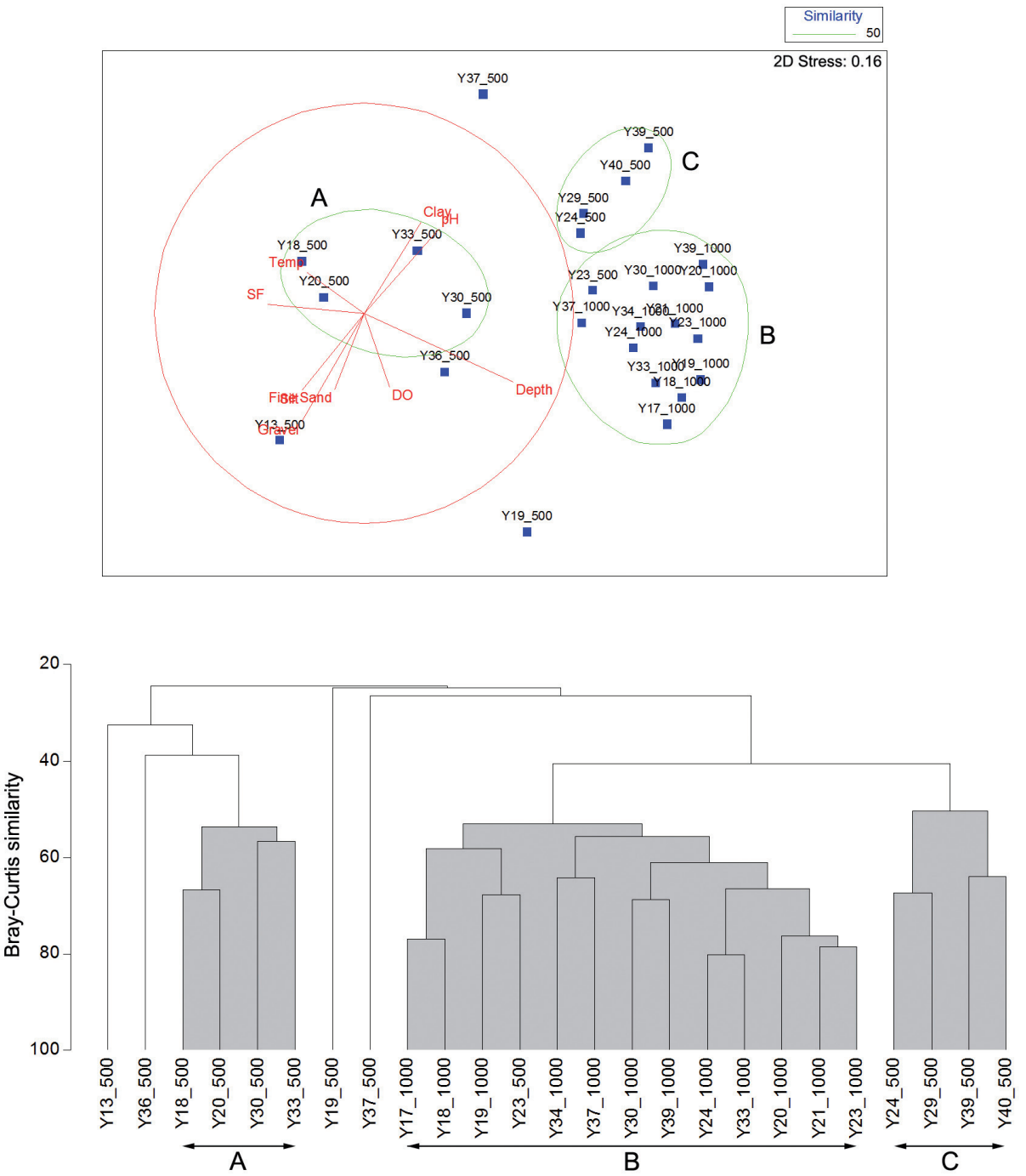

Fig. 5: MDS plot and dendrogram of the sampled stations, based on mollusc abundance data (sum of three replicates), and correlation of environmental variables with MDS axes, represented by superimposed vectors. Similarity among the stations was determined using the Bray-Curtis similarity index and was then superimposed on the MDS plot. The groups of stations (A, B and C) are highlighted in grey on the dendrogram.

Fig. 6: Species new to the marine molluscan fauna of Turkey (*Akritogyra conspicua* and *Liostomia hansgei*) and to the Sea of Marmara (*Benthonella tenella*, *Odostomia silesui*, *Syrnola minuta* and *Crenilabium exile*).

tat, reduced sediment microhabitat and carbonate crust microhabitat of cold seeps located in the north-east Central Basin. Although a limited number of samples were evaluated in that study, the number of molluscan species was high (23 species) as the samples were taken from the specific microhabitats of cold seeps, generally preferred by symbiont-bearing species (Salas & Woodside, 2002; Olu-Le Roy *et al.*, 2004; Brissac *et al.*, 2011).

Lucinoma kazani and *Myrtea amorpha*, which are symbiont-bearing lucinid species, were newly reported from the Sea of Marmara by Ritt *et al.* (2010). Among these two species, *L. kazani* was only found at one station (Y19_500 m) with its congeneric *L. borealis* (Fig. 7), while *M. amorpha* was encountered at only two stations (Y19_500 m and Y36_1000 m). *Falcidens gutturosus, Putzeysia wiseri* and *Laeviphitus verduini,* which were identified in this study, were the other molluscan species reported by Ritt *et al.* (2010) in the cold seep microhabitats in the bathyal zones of the Sea of Marmara. According to these findings, some of our stations (i.e.Y19_500 m and Y36_1000 m) might have been close to the cold seeps favouring symbiont-bearing species.

During research carried out between 1994 and 1999 off the northern coast of Israel, at depths between 734 and 1558 m, 23 live molluscan species were reported (Bogi & Galil, 2004). In the northern part of Crete, Koutsoubas *et al.* (2000) recorded 31, 24, 22 and 10 molluscan species at depths of 500, 700, 1000 and 1570 m, respectively.

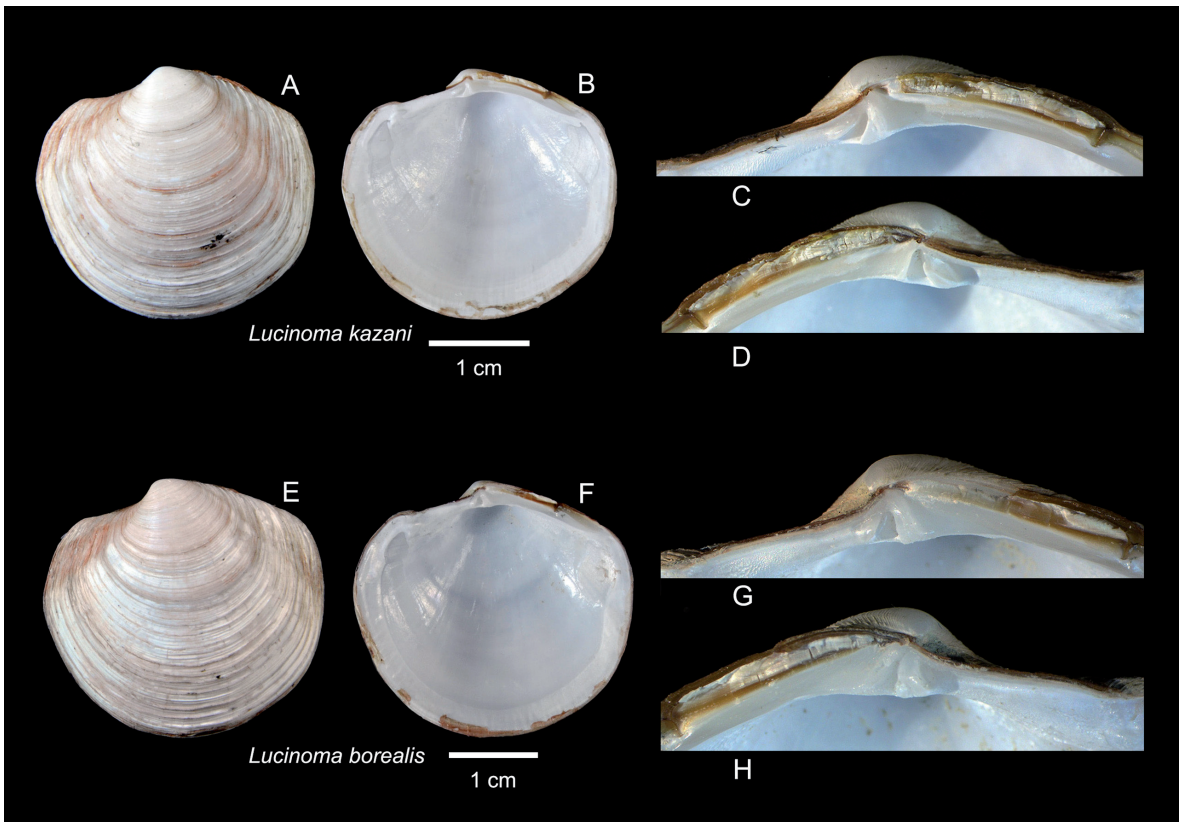

Fig. 7: External view of the left valve (A), internal view of the right valve (B), hinge line of the right (C) and the left (D) valves of *Lucinoma kazani*. External view of the left valve (E), internal view of the right valve (F), hinge line of the right (G) and the left (H) valves of *L. borealis*.

Mastrototaro *et al.* (2010) identified 35 molluscan species from the white coral bank off Cape Santa Maria di Leuca (Ionian Sea) at depths between 310 and 803 m. According to the results of all these studies, the molluscan assemblages in the bathyal zone of the Sea of Marmara were similar to those identified in the other parts of the eastern Mediterranean.

Lucinoma borealis is known to be distributed in shallower areas than those determined by this study (Salas & Woodside, 2002). This could be due to the distinctive ecological characteristics of the Sea of Marmara.

Gastropoda was the dominant group in terms of number of species and number of individuals. Gastropod dominance is due to the abundance of *Parthenina flexuosa*, which is a small pyramidellid mollusc known to be an ectoparasite, feeding on the body fluids of some invertebrates, such as polychaetes, molluscs and echinoderms (Robertson & Mau-Lastovicka, 1979). The high abundance of the echinoid echinoderm *Brissopsis lyrifera* (Forbes, 1841), with three specimens per square meter in the bathyal bottoms of the Sea of Marmara (unpublished data), could have stimulated the dense settlement of this ectoparasitic gastropod.

According to the MDS plot and the correlation values between the environmental variables and MDS axes, the depth was found to be the main factor affecting molluscan assemblages in the study area. The granulometric features of the sediment also seem to have influence the distribution of molluscan species in the area. These factors are known to have strong impacts on the distribution patterns of zoobenthic organisms in the benthic ecosystem (Tselepides *et al*., 2000; Labrune *et al.*, 2007; Çınar *et al*., 2012). Pancucci-Papadopoulou *et al.* (1999) note that sediment structure, depth and hydrological conditions could play a synergistic role in the discrimination of macrobenthic communities. According to Gray (2002), sediment structure and food availability could be considered as the main factors determining faunal biodiversity in the deeper zones of the seas.

As a result of this study, the number of molluscan species distributed in the 500 m and deeper zones of the Sea of Marmara increased to 42 (Table 5). Besides, some species on the list, such as *Myrtea spinifera* (Montagu, 1803) distributed in the shallower depths and quite similar to *Myrtea amorpha* (Sturany, 1896) might have been identified incorrectly.

This study presents the recent status of molluscan communities in the bathyal zone of the Sea of Marmara. In order to gain a better understanding of the deep-sea fauna of the Sea of Marmara, more detailed studies, using bottom-trawling and under-water equipment via ROV, are required.

Table 5. List of species distributed in the 500 m and deeper zones of the Sea of Marmara and references.

Species	Reference
Falcidens gutturosus (Kowalewsky, 1901)	Ritt *et al*., 2010
Putzeysia wiseri (Calcara, 1842)	Ritt *et al*., 2010
Akritogyra conspicua (Monterosato, 1880)	This study
Bittium submamillatum (de Rayneval & Ponzi, 1854)	This study
Alvania cimicoides (Forbes, 1844)	This study
Benthonella tenella (Jeffreys, 1869)	This study
Pusillina inconspicua (Alder, 1844)	This study
Laeviphitus verduini van Aartsen, Bogi & Giusti, 1989	Ritt *et al*., 2010
Ceratia proxima (Forbes & Hanley, 1850)	This study
Hyala vitrea (Montagu, 1803)	This study
Liostomia hansgei Warén, 1991	This study
Mangelia nuperrima (Tiberi, 1855)	This study
Megastomia conoidea (Brocchi, 1814)	This study
Odostomia silesui Nofroni, 1988	This study
Odostomia unidentata (Montagu, 1803)	This study
Parthenina flexuosa (Monterosato, 1874)	This study
Parthenina interstincta (Adams, J., 1797)	This study
Syrnola minuta H. Adams, 1869	This study
Aporrhais serresianus (Michaud, 1828)	Ostroumoff, 1896
Euspira fusca (Blainville, 1825)	Ostroumoff, 1896
Pterotrachea coronata Forsskål in Niebuhr, 1775	Ostroumoff, 1896
Turbonilla micans (Monterosato, 1875)	This study
Crenilabium exile (Jeffreys, 1870)	This study
Roxania utriculus (Brocchi, 1814)	This study
Cylichna cylindracea (Pennant, 1777)	This study
Yoldiella philippiana (Nyst, 1845)	Ostroumoff, 1896
Yoldiella striolata (Brugnone, 1876)	Ritt *et al*., 2010
Delectopecten vitreus (Gmelin, 1791)	Ostroumoff, 1896
Flexopecten glaber (Linnaeus, 1758)	Ostroumoff, 1896
Lucinoma borealis (Linnaeus, 1767)	Ostroumoff, 1896
Lucinoma kazani Salas & Woodside, 2002	Ritt *et al*., 2010
Myrtea amorpha (Sturany, 1896)	Ritt *et al*., 2010
Myrtea spinifera (Montagu, 1803)	Ostroumoff, 1896
Kurtiella bidentata (Montagu, 1803)	Ostroumoff, 1896
Abra longicallus (Scacchi, 1835)	Ostroumoff, 1896
Kelliella miliaris (Philippi, 1844)	Ostroumoff, 1896
Isorropodon perplexum Sturany, 1896	Ritt *et al*., 2010
Timoclea ovata (Pennant, 1777)	Ostroumoff, 1896
Corbula gibba (Olivi, 1792)	Ostroumoff, 1896
Xylophaga dorsalis (Turton, 1819)	Ostroumoff, 1896
Cuspidaria cuspidata (Olivi, 1792)	Sturany, 1895
Entalina tetragona (Brocchi, 1814)	This study

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